US010404982B2

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Alshina et al.

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(54) **PER-SAMPLE PREDICTION ENCODING APPARATUS AND METHOD**

(71) Applicant: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(72) Inventors: **Elena Alshina**, Suwon-si (KR); **Alexander Alshin**, Suwon-si (KR)

(73) Assignee: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 158 days.

(21) Appl. No.: **15/524,829**

(22) PCT Filed: **Nov. 4, 2015**

(86) PCT No.: **PCT/KR2015/011810**
§ 371 (c)(1),
(2) Date: **May 5, 2017**

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PCT Pub. Date: **May 12, 2016**

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Related U.S. Application Data

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(51) **Int. Cl.**
H04N 19/119 (2014.01)
H04N 19/102 (2014.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04N 19/119*** (2014.11); ***H04N 19/102*** (2014.11); ***H04N 19/124*** (2014.11); ***H04N 19/44*** (2014.11); ***H04N 19/61*** (2014.11)

(58) **Field of Classification Search**
CPC .. H04N 19/119; H04N 19/102; H04N 19/124; H04N 19/44; H04N 19/61
(Continued)

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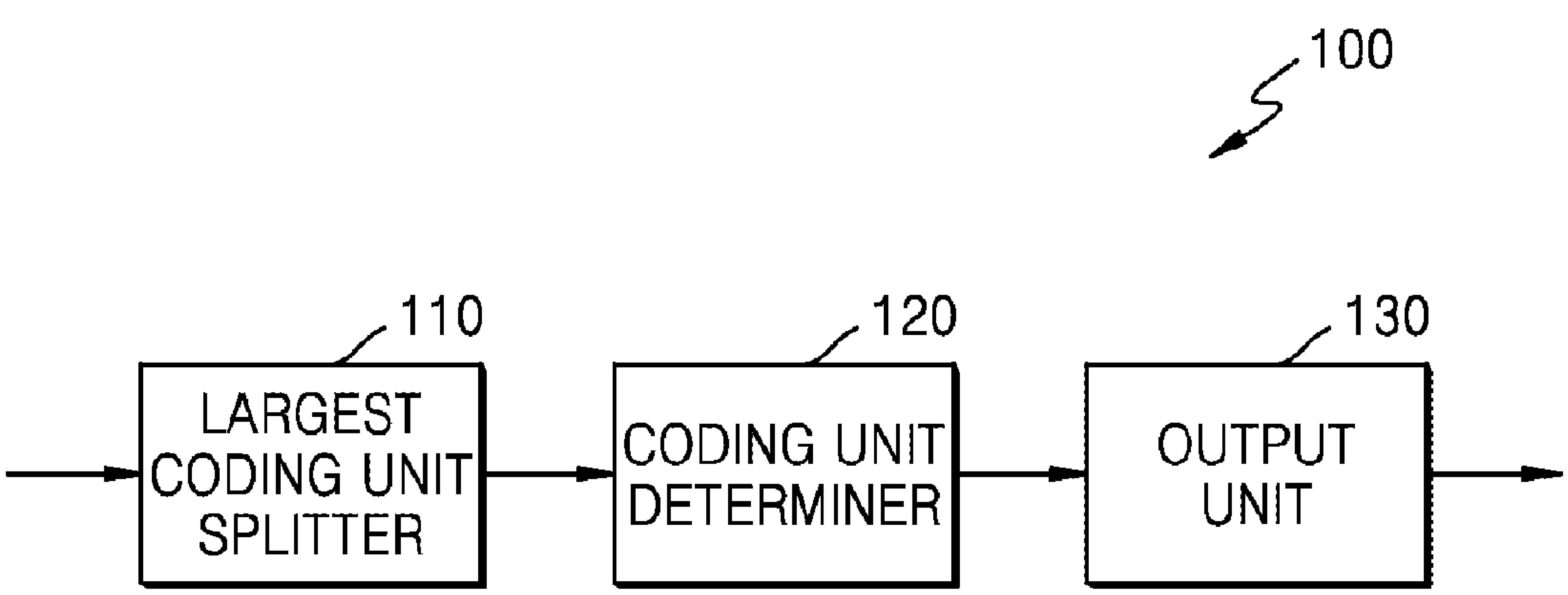
Primary Examiner — Nguyen T Truong
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

A video decoding apparatus includes: a splitter configured to split an image into at least one block; a predictor configured to predict a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a first weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and a decoder configured to decode the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

8 Claims, 41 Drawing Sheets



(51) **Int. Cl.**

H04N 19/124	(2014.01)
H04N 19/44	(2014.01)
H04N 19/61	(2014.01)

(58) **Field of Classification Search**

USPC 375/240.12

See application file for complete search history.

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FIG. 1

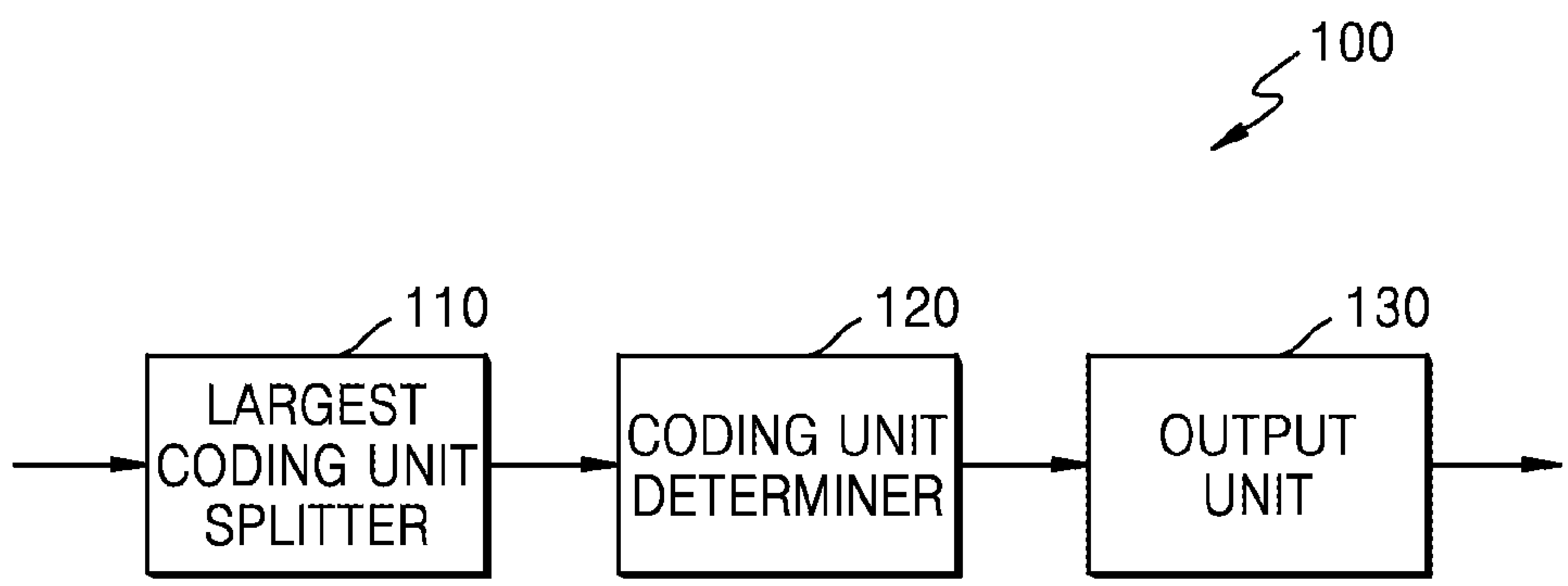

100
110
120
130
LARGEST
CODING UNIT
SPLITTER
CODING UNIT
DETERMINER
OUTPUT
UNIT

FIG. 2

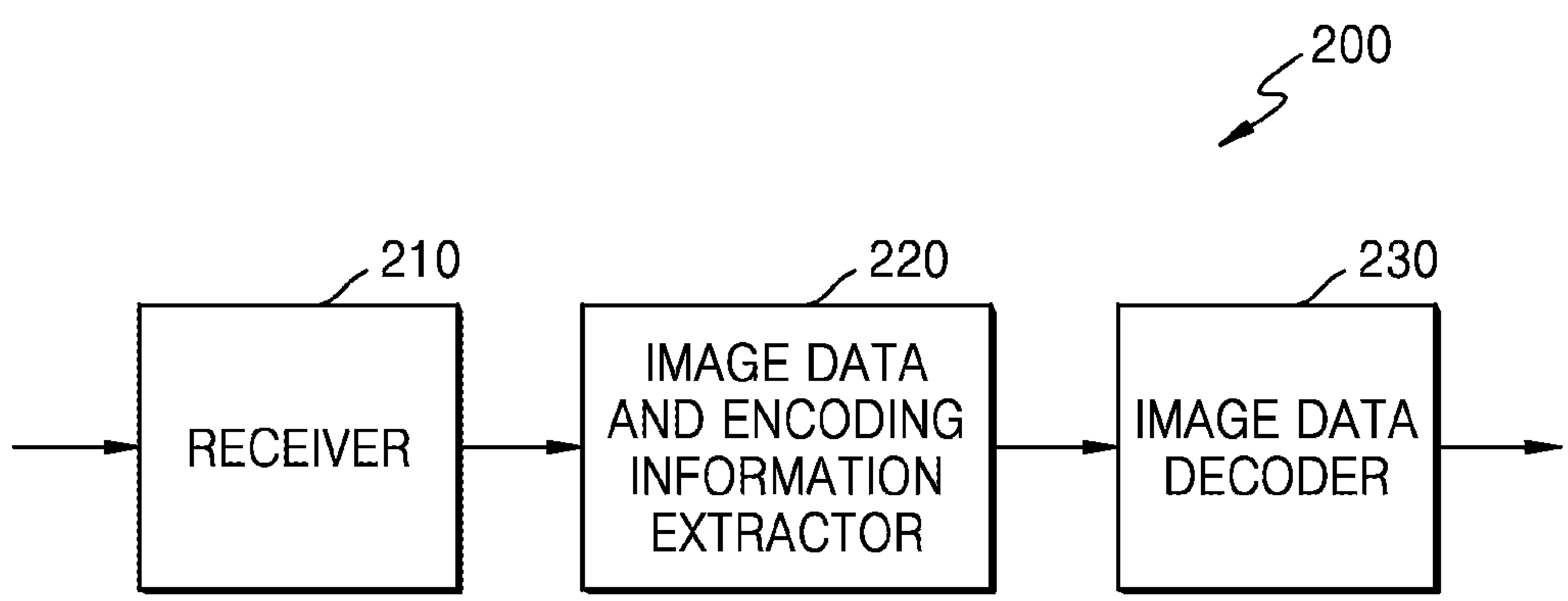

200
210
220
230
RECEIVER
IMAGE DATA
AND ENCODING
INFORMATION
EXTRACTOR
IMAGE DATA
DECODER

FIG. 3

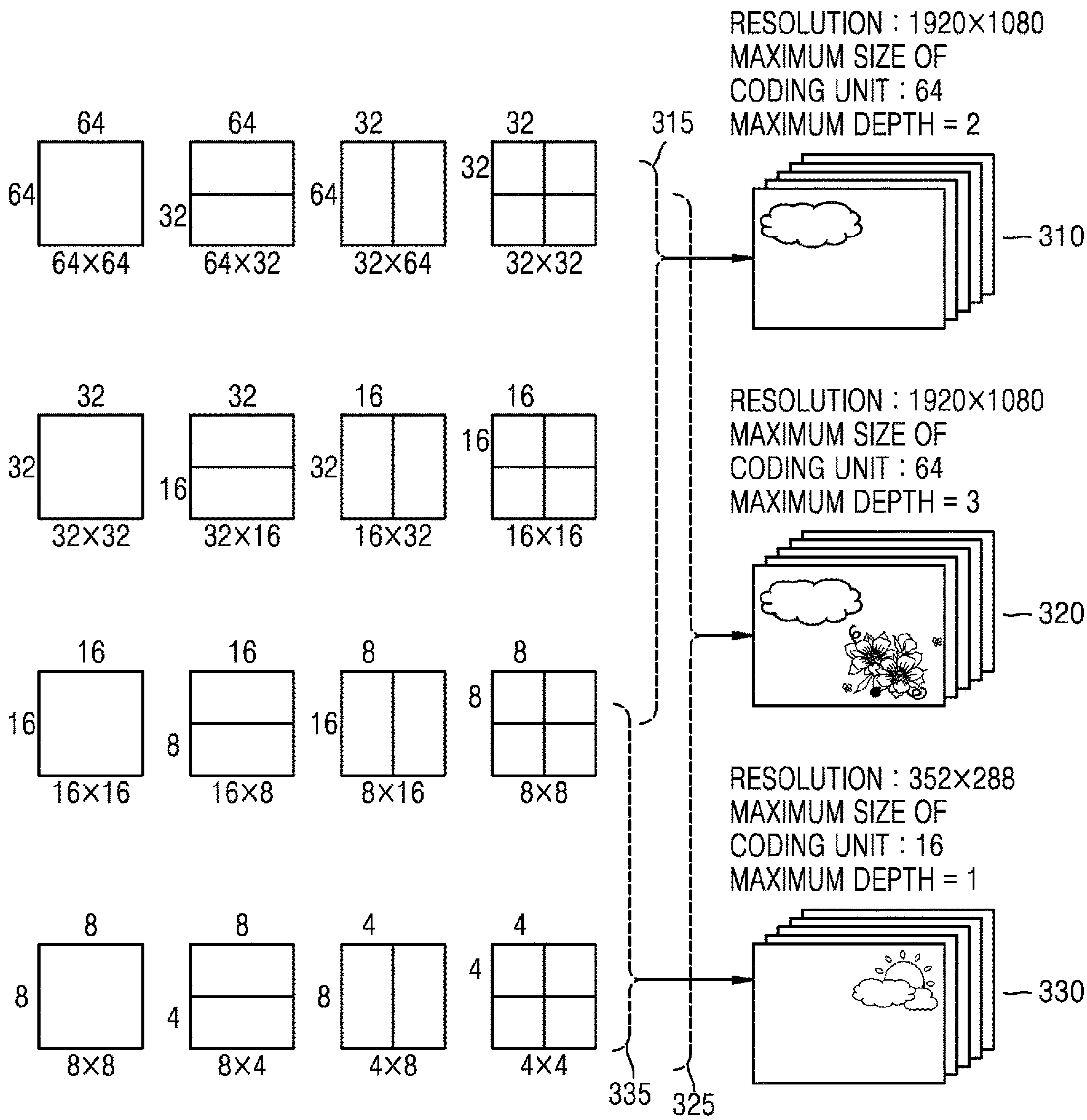

RESOLUTION : 1920×1080
MAXIMUM SIZE OF
CODING UNIT : 64
MAXIMUM DEPTH = 2
RESOLUTION : 1920×1080
MAXIMUM SIZE OF
CODING UNIT : 64
MAXIMUM DEPTH = 3
RESOLUTION : 352×288
MAXIMUM SIZE OF
CODING UNIT : 16
MAXIMUM DEPTH = 1
64×64
64×32
32×64
32×32
32×32
32×16
16×32
16×16
16×16
16×8
8×16
8×8
8×8
8×4
4×8
4×4
310
320
330
315
325
335

FIG. 4

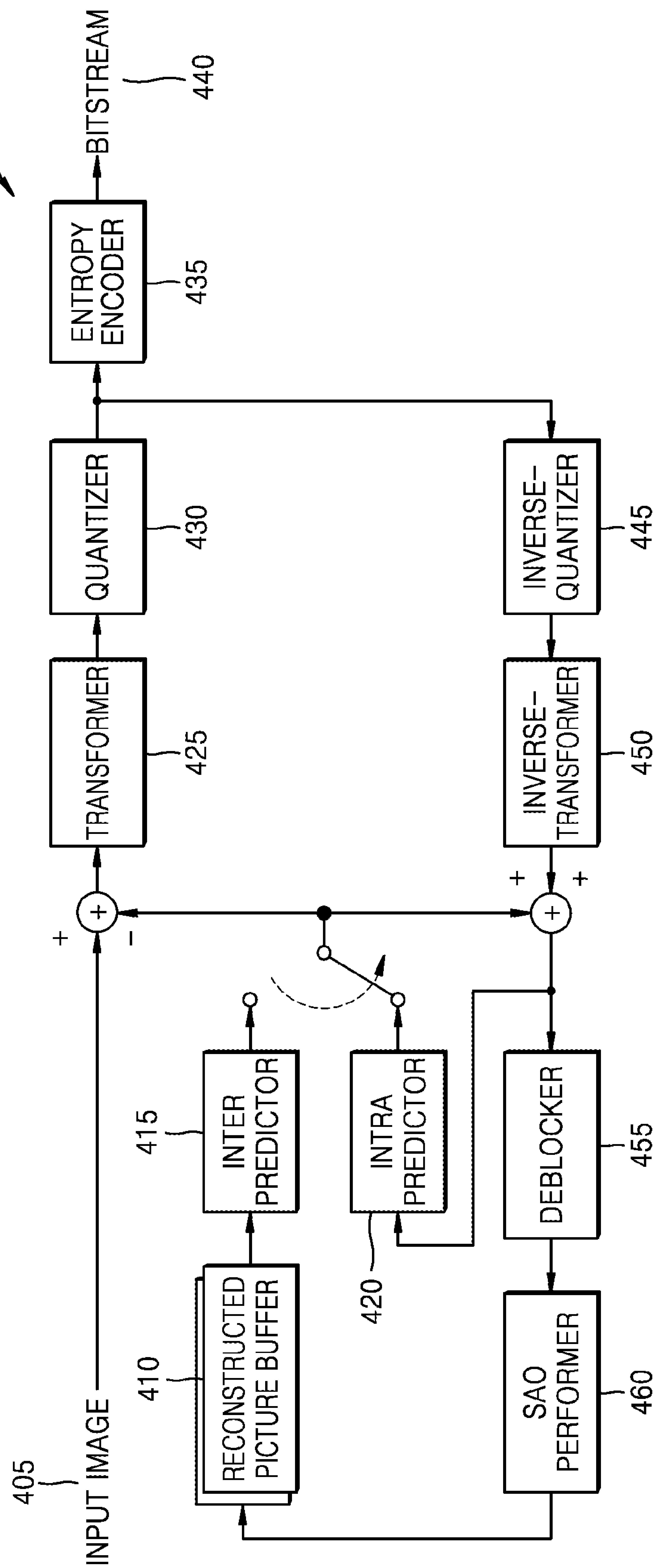

400
BITSTREAM
440
ENTROPY ENCODER
435
QUANTIZER
430
TRANSFORMER
425
INVERSE-QUANTIZER
445
INVERSE-TRANSFORMER
450
INTER PREDICTOR
415
INTRA PREDICTOR
420
DEBLOCKER
455
SAO PERFORMER
460
RECONSTRUCTED PICTURE BUFFER
410
INPUT IMAGE
405
+
-
+
+

FIG. 5

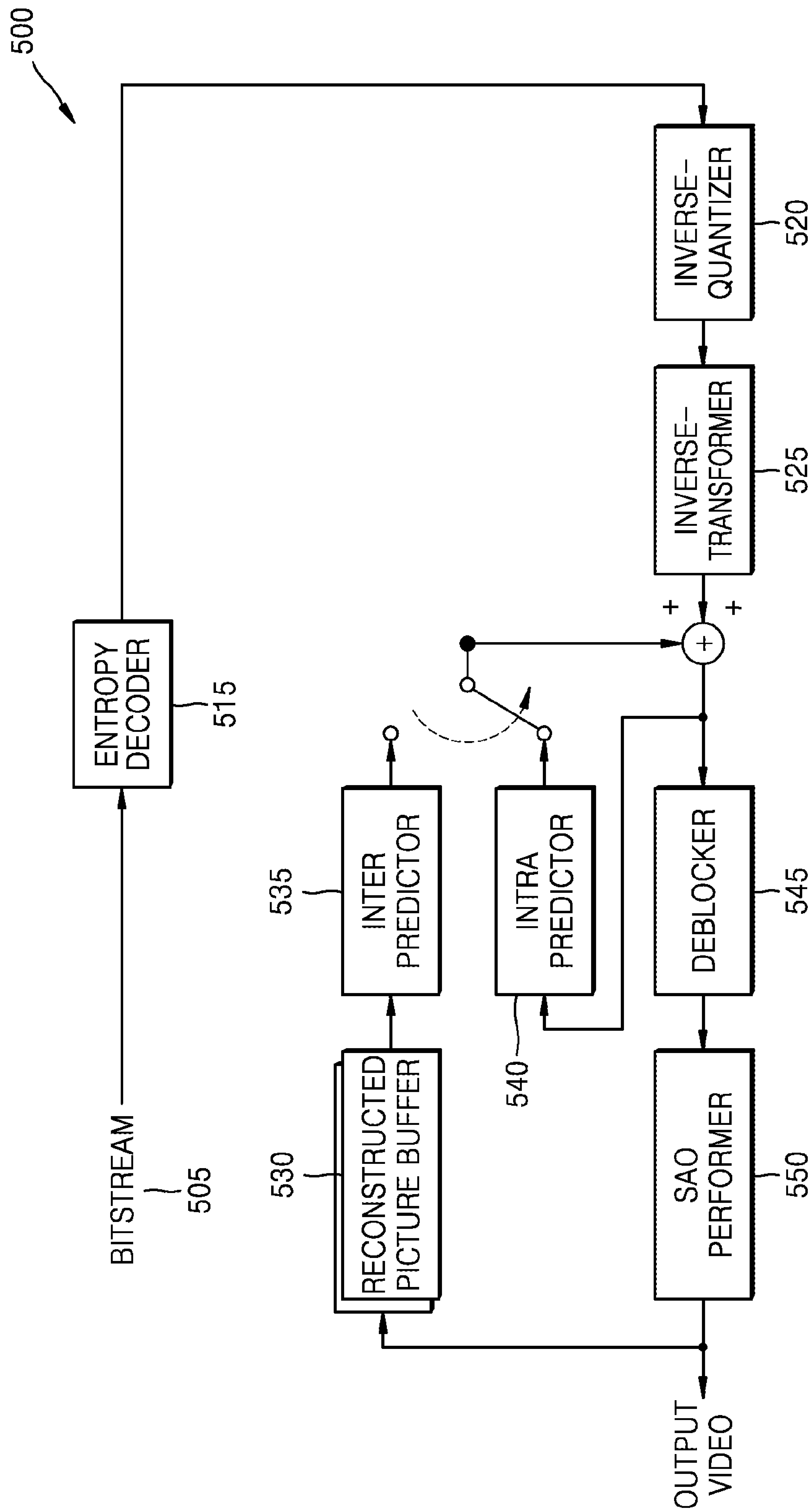

500
BITSTREAM
505
ENTROPY DECODER
515
INVERSE-QUANTIZER
520
INVERSE-TRANSFORMER
525
+
+
RECONSTRUCTED PICTURE BUFFER
530
INTER PREDICTOR
535
INTRA PREDICTOR
540
DEBLOCKER
545
SAO PERFORMER
550
OUTPUT VIDEO

FIG. 6

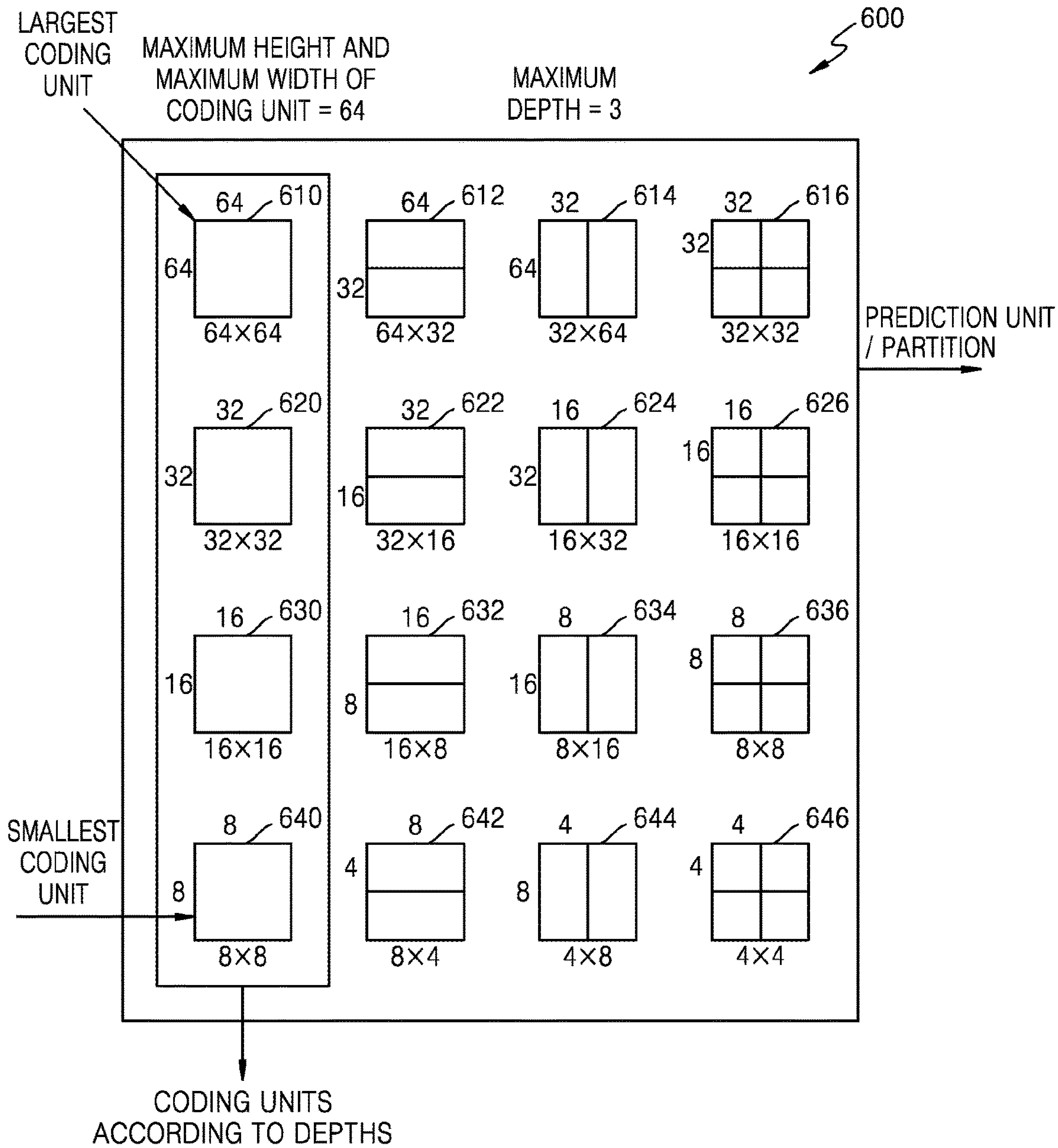

600
LARGEST CODING UNIT
MAXIMUM HEIGHT AND MAXIMUM WIDTH OF CODING UNIT = 64
MAXIMUM DEPTH = 3
64
610
64
64×64
64
612
32
64×32
32
614
64
32×64
32
616
32
32×32
PREDICTION UNIT / PARTITION
32
620
32
32×32
32
622
16
32×16
16
624
32
16×32
16
626
16
16×16
16
630
16
16×16
16
632
8
16×8
8
634
16
8×16
8
636
8
8×8
SMALLEST CODING UNIT
8
640
8
8×8
8
642
4
8×4
4
644
8
4×8
4
646
4
4×4
CODING UNITS ACCORDING TO DEPTHS

FIG. 7

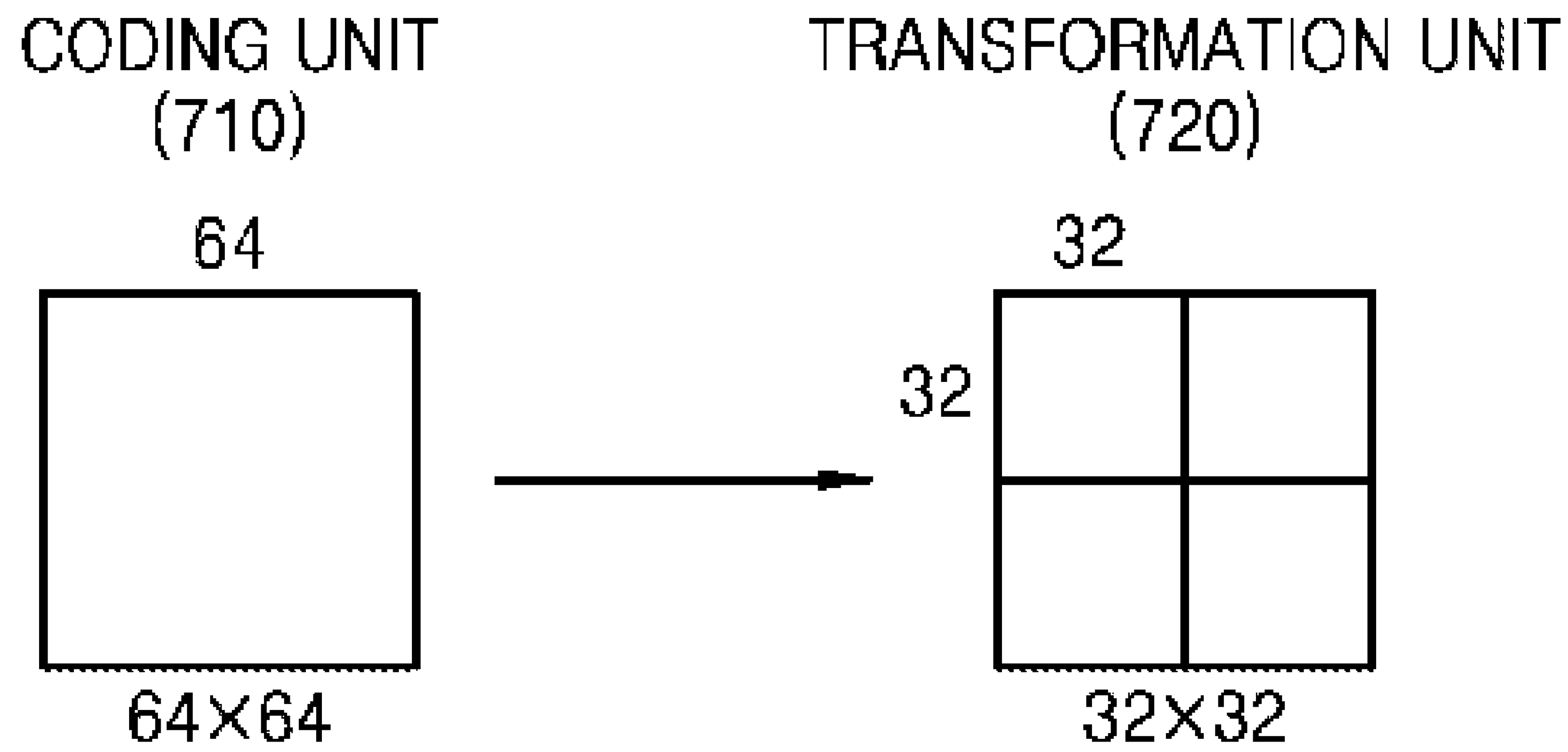

CODING UNIT
(710)
64
64×64
TRANSFORMATION UNIT
(720)
32
32
32×32

FIG. 8

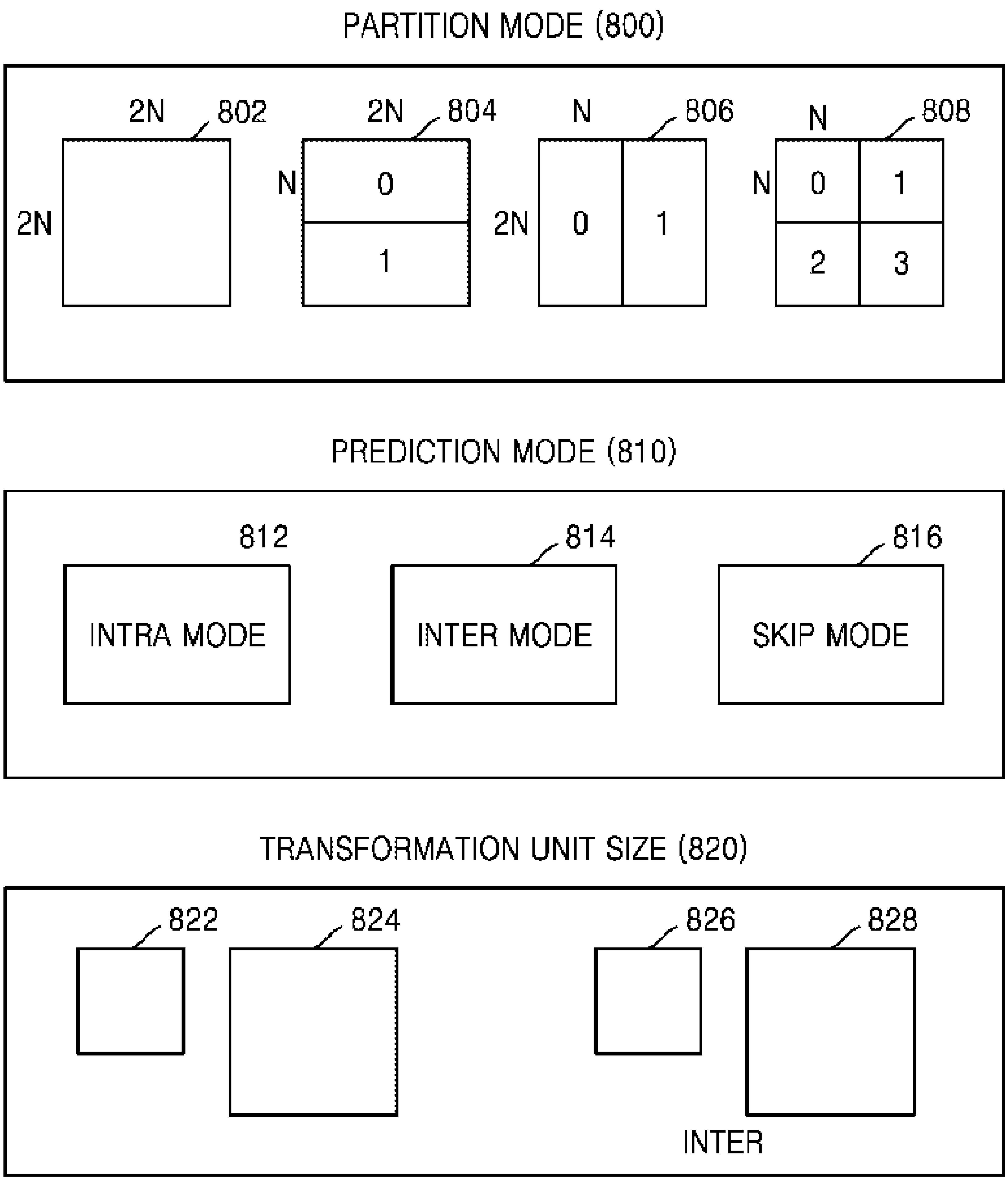

PARTITION MODE (800)
2N
802
2N
2N
804
N
0
1
N
806
2N
0
1
N
808
N
0
1
2
3
PREDICTION MODE (810)
812
INTRA MODE
814
INTER MODE
816
SKIP MODE
TRANSFORMATION UNIT SIZE (820)
822
824
826
828
INTER

FIG. 9

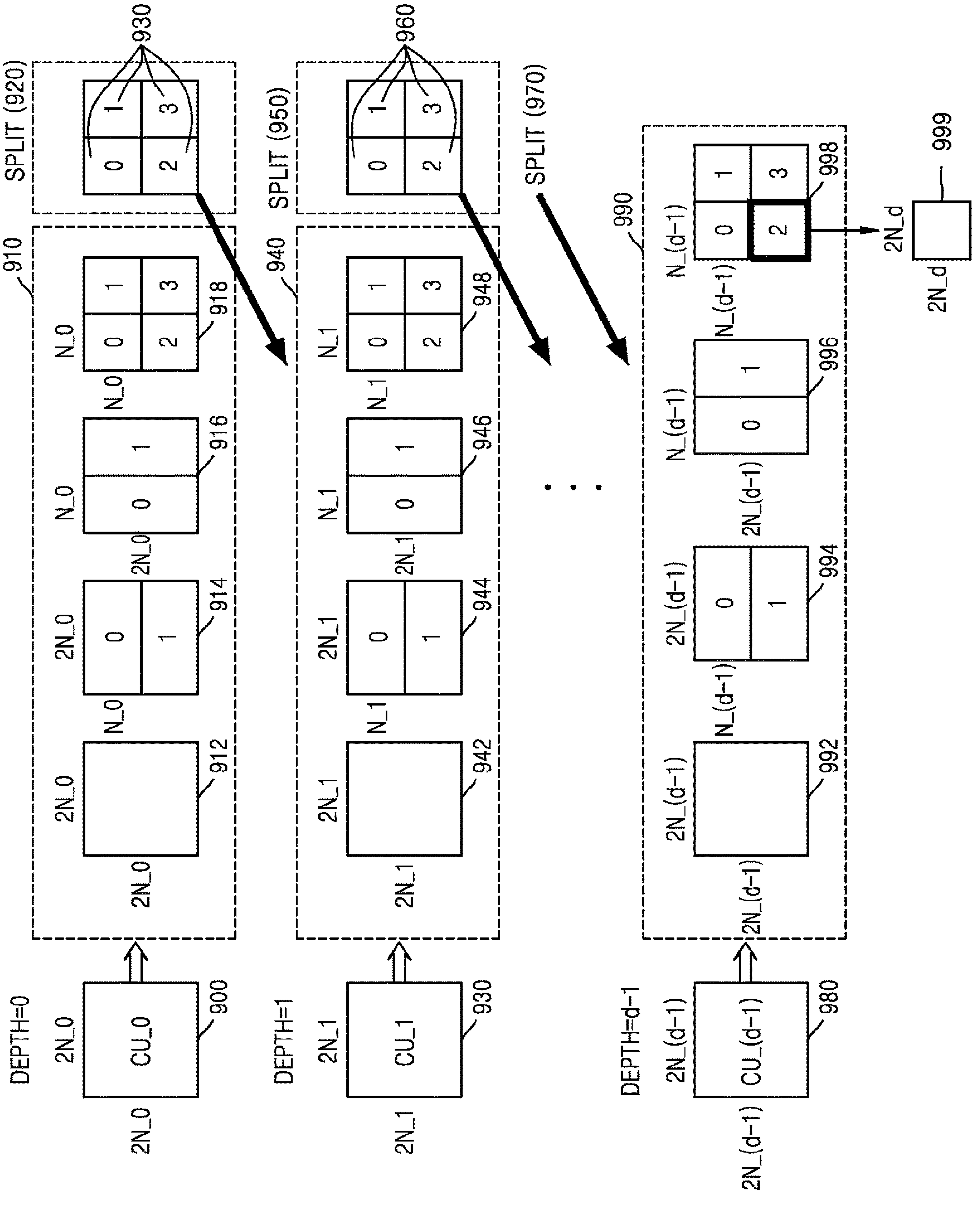
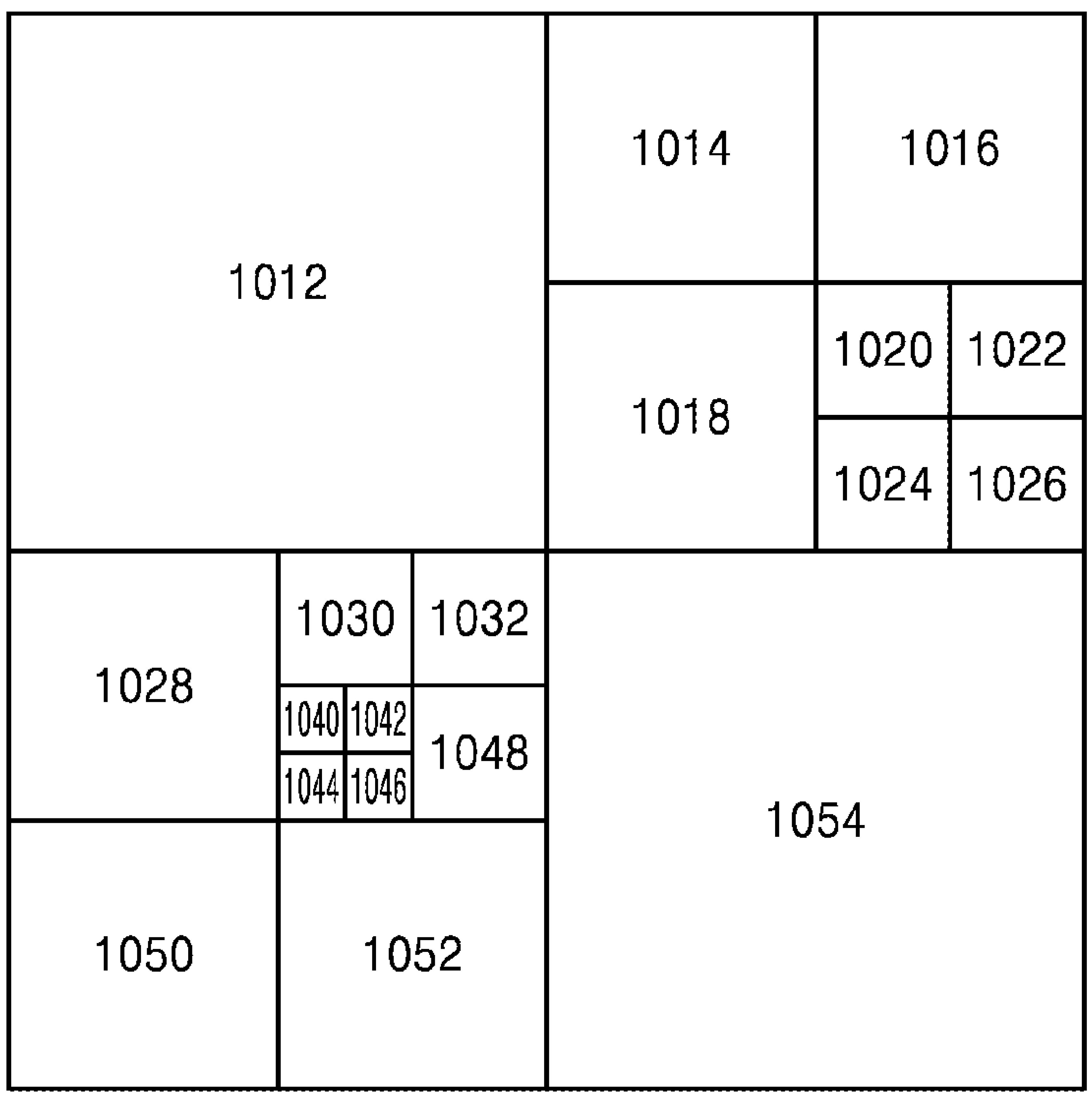

DEPTH=0
2N_0
2N_0
CU_0
900
910
2N_0
2N_0
912
2N_0
N_0
0
1
914
N_0
2N_0
0
1
916
N_0
N_0
0
1
2
3
918
SPLIT (920)
0
1
2
3
930
DEPTH=1
2N_1
2N_1
CU_1
930
940
2N_1
2N_1
942
2N_1
N_1
0
1
944
N_1
2N_1
0
1
946
N_1
N_1
0
1
2
3
948
SPLIT (950)
0
1
2
3
960
SPLIT (970)
DEPTH=d-1
2N_(d-1)
2N_(d-1)
CU_(d-1)
980
990
2N_(d-1)
2N_(d-1)
992
2N_(d-1)
N_(d-1)
0
1
994
N_(d-1)
2N_(d-1)
0
1
996
N_(d-1)
N_(d-1)
0
1
2
3
998
2N_d
2N_d
999

FIG. 10



CODING UNIT (1010)

FIG. 11

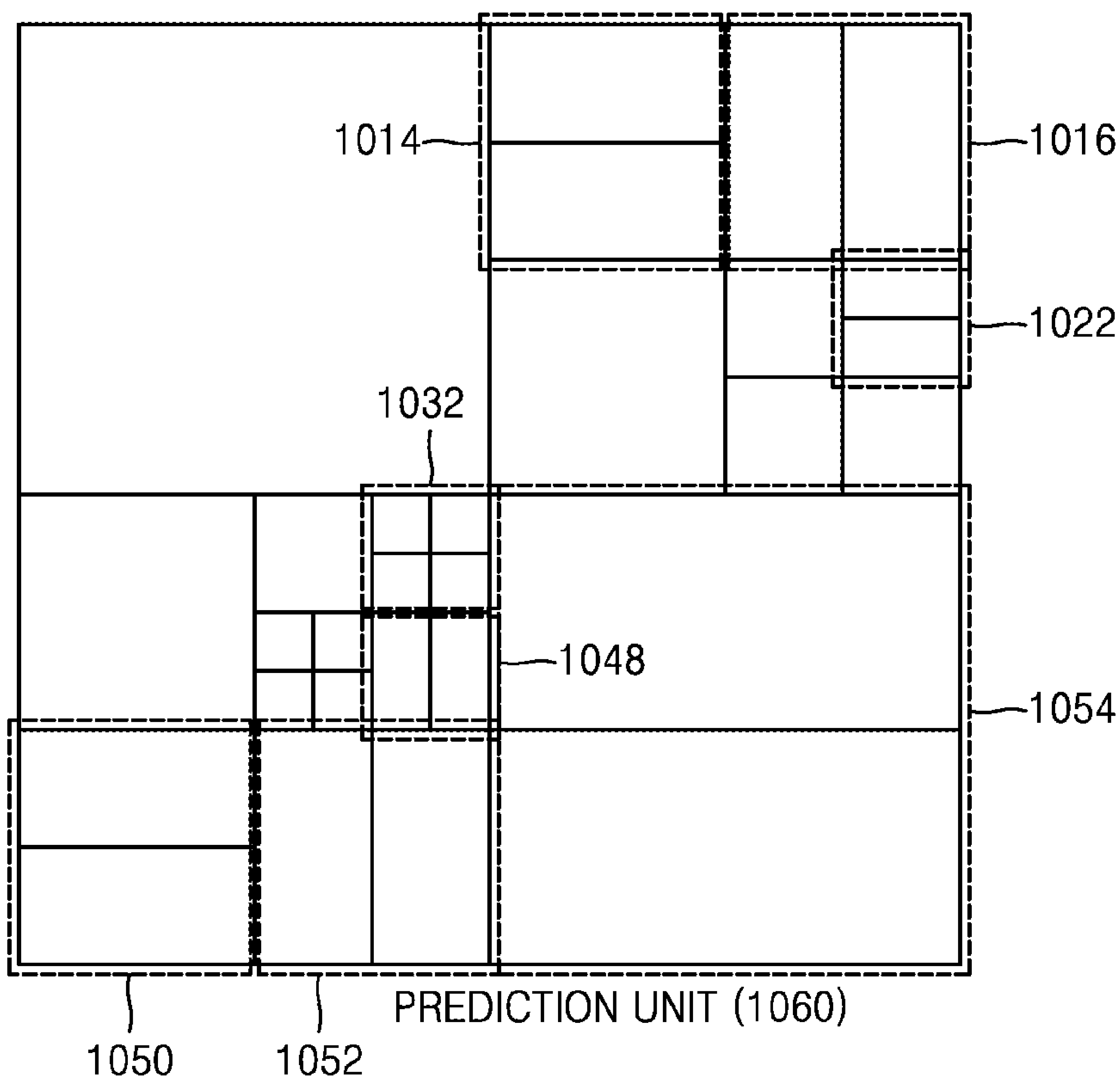

1014
1016
1022
1032
1048
1054
1050
1052
PREDICTION UNIT (1060)

FIG. 12

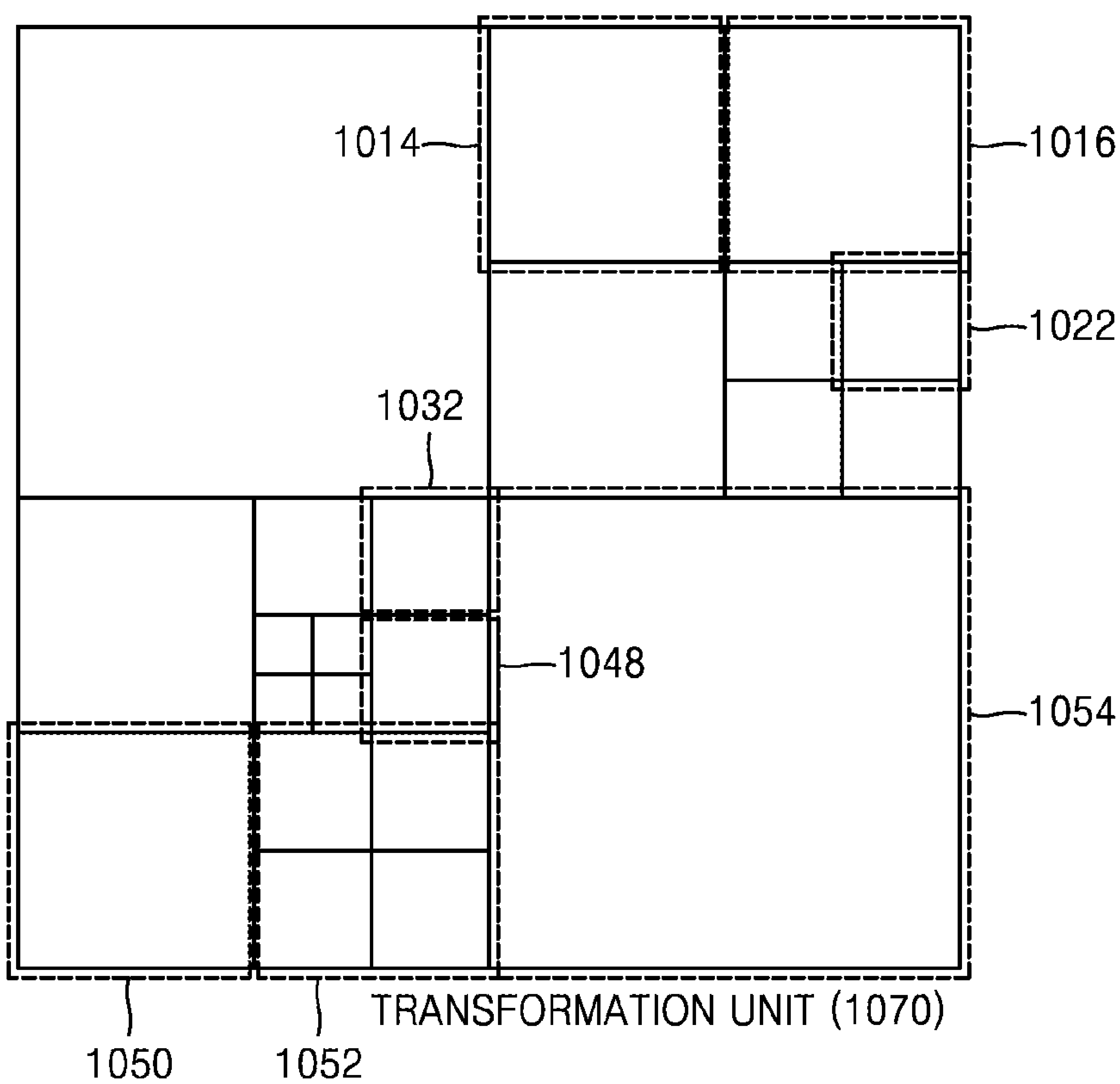

1014
1016
1022
1032
1048
1054
1050
1052
TRANSFORMATION UNIT (1070)

FIG. 13

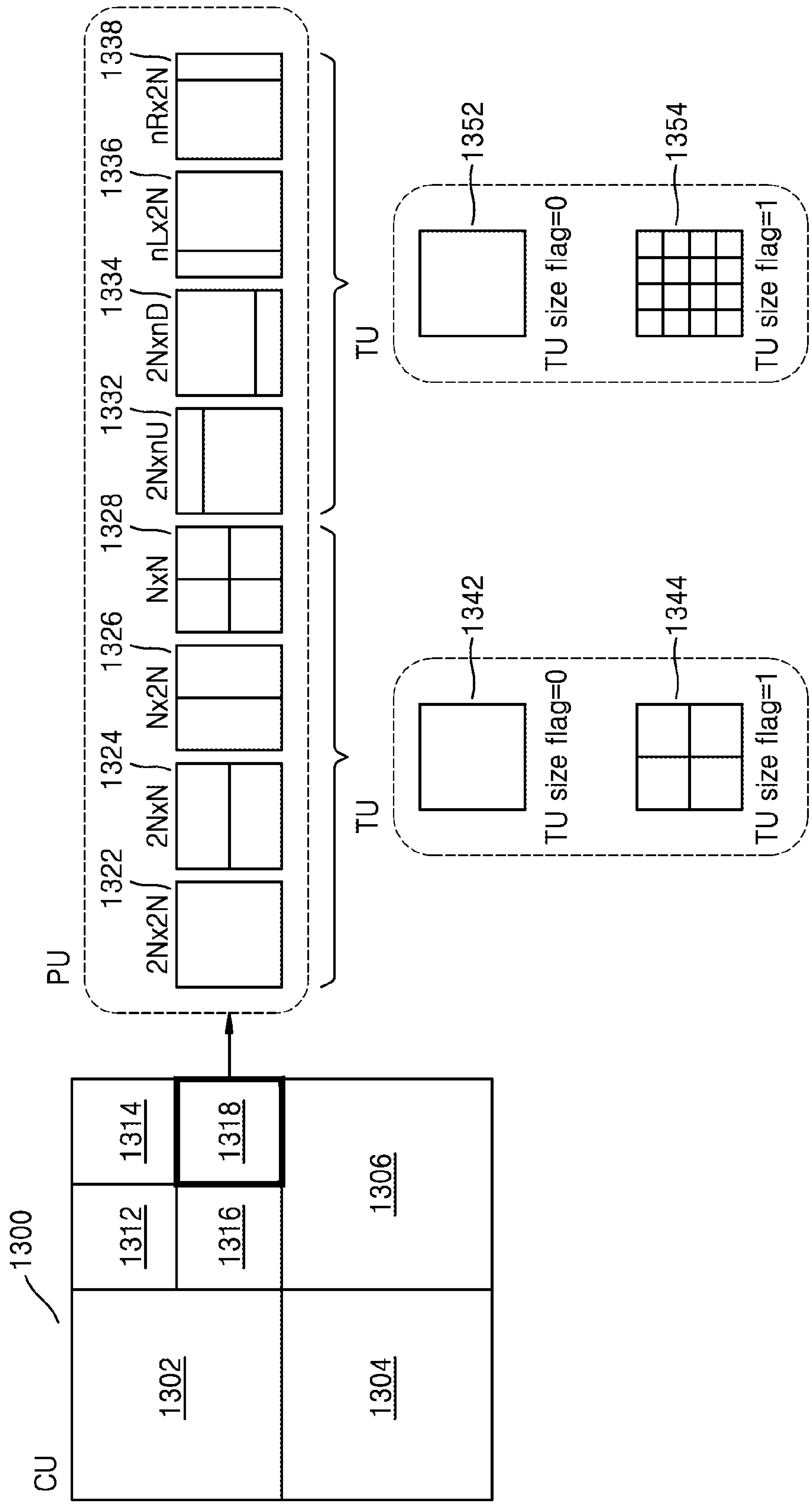

CU
1300
1302
1304
1312
1314
1316
1318
1306
PU
2Nx2N
1322
2NxN
1324
Nx2N
1326
NxN
1328
2NxnU
1332
2NxnD
1334
nLx2N
1336
nRx2N
1338
TU
1342
TU size flag=0
1344
TU size flag=1
TU
1352
TU size flag=0
1354
TU size flag=1

FIG. 14

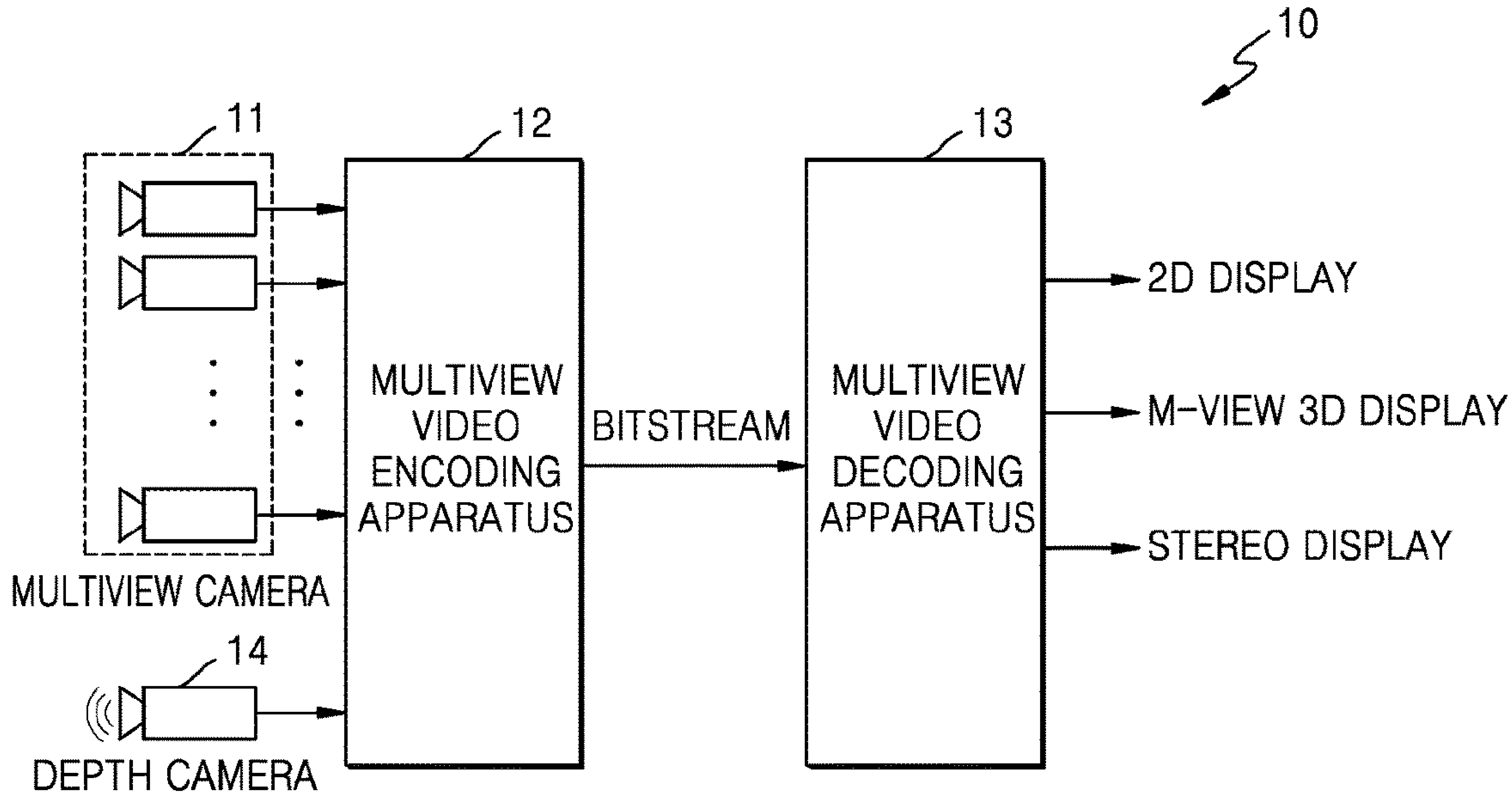

10
11
12
13
MULTIVIEW VIDEO ENCODING APPARATUS
BITSTREAM
MULTIVIEW VIDEO DECODING APPARATUS
2D DISPLAY
M-VIEW 3D DISPLAY
STEREO DISPLAY
MULTIVIEW CAMERA
14
DEPTH CAMERA

FIG. 15

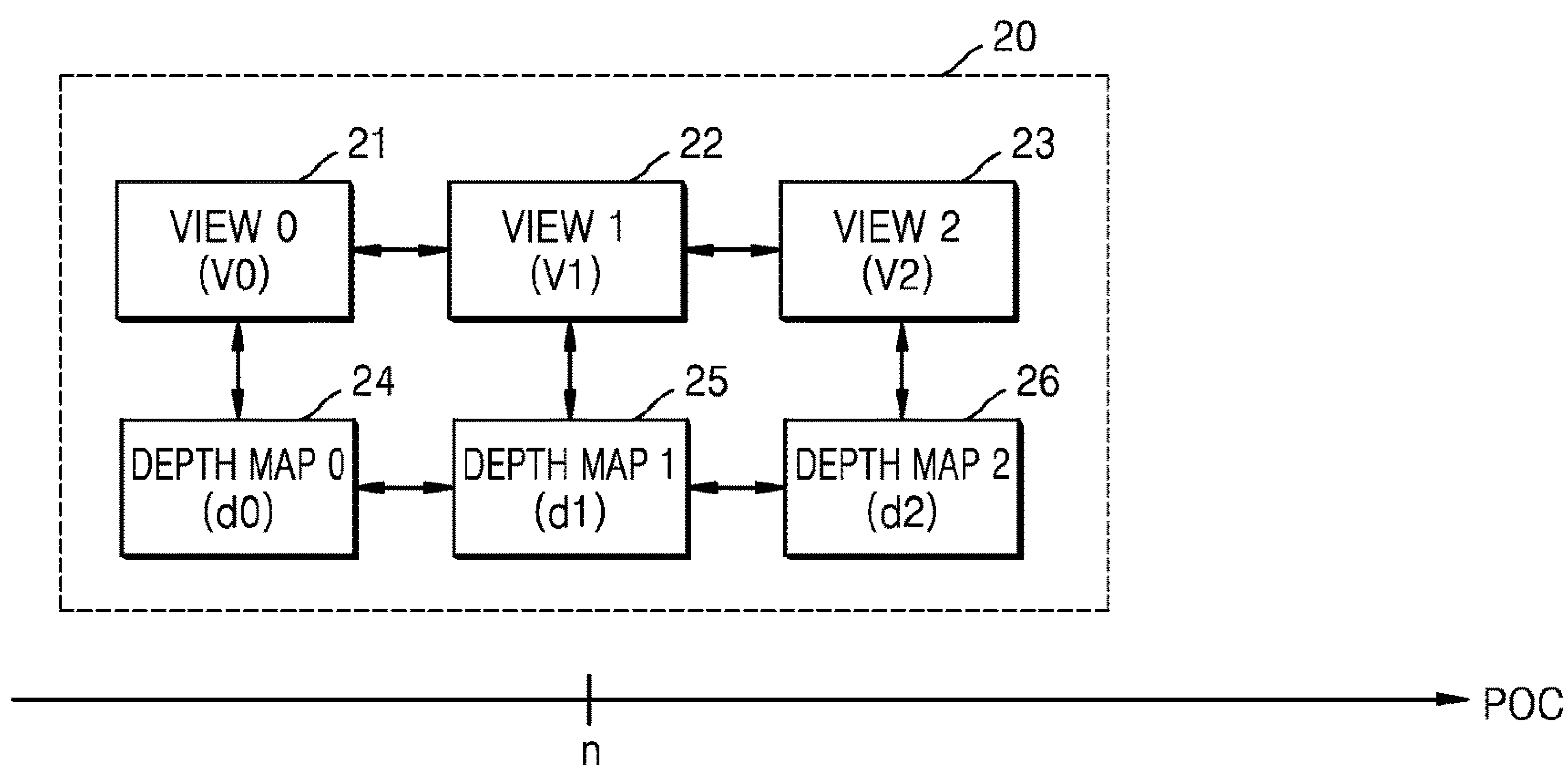

20
21
22
23
VIEW 0 (V0)
VIEW 1 (V1)
VIEW 2 (V2)
24
25
26
DEPTH MAP 0 (d0)
DEPTH MAP 1 (d1)
DEPTH MAP 2 (d2)
POC
n

FIG. 16

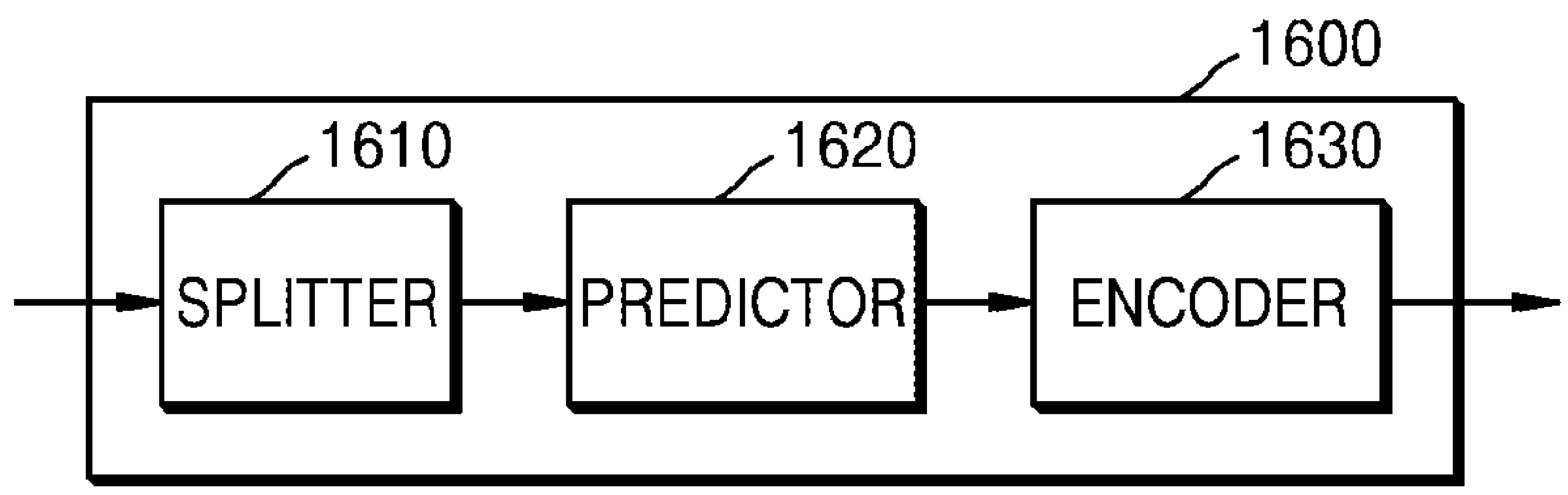

1600
1610
1620
1630
SPLITTER
PREDICTOR
ENCODER

FIG. 17

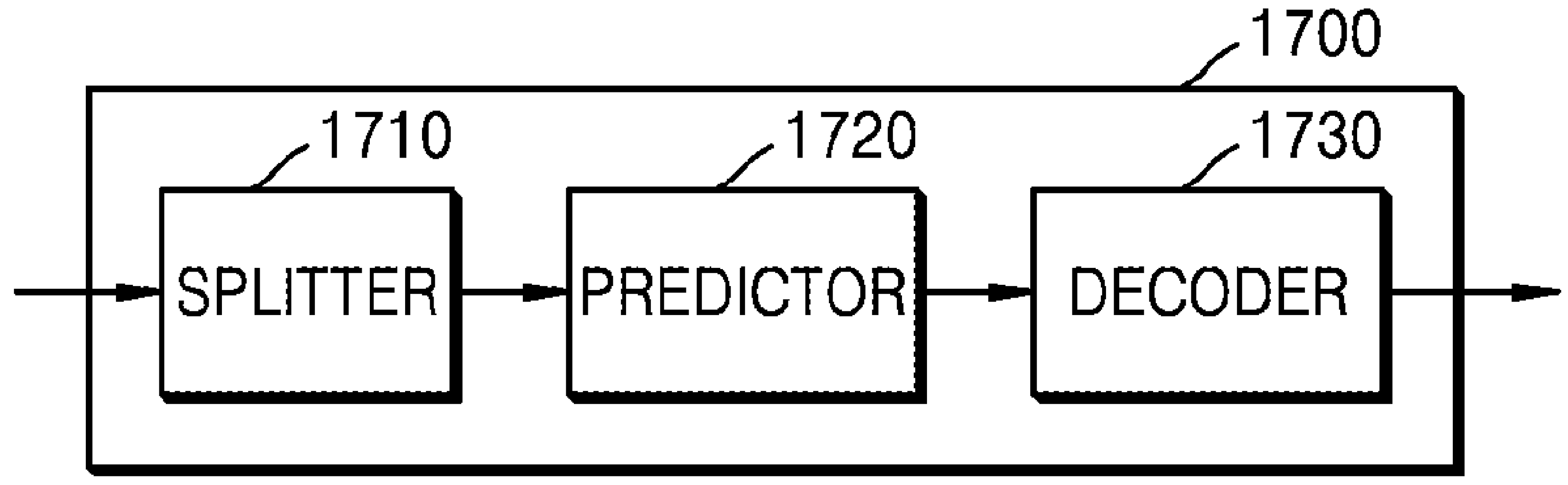

1700
1710
1720
1730
SPLITTER
PREDICTOR
DECODER

FIG. 18A

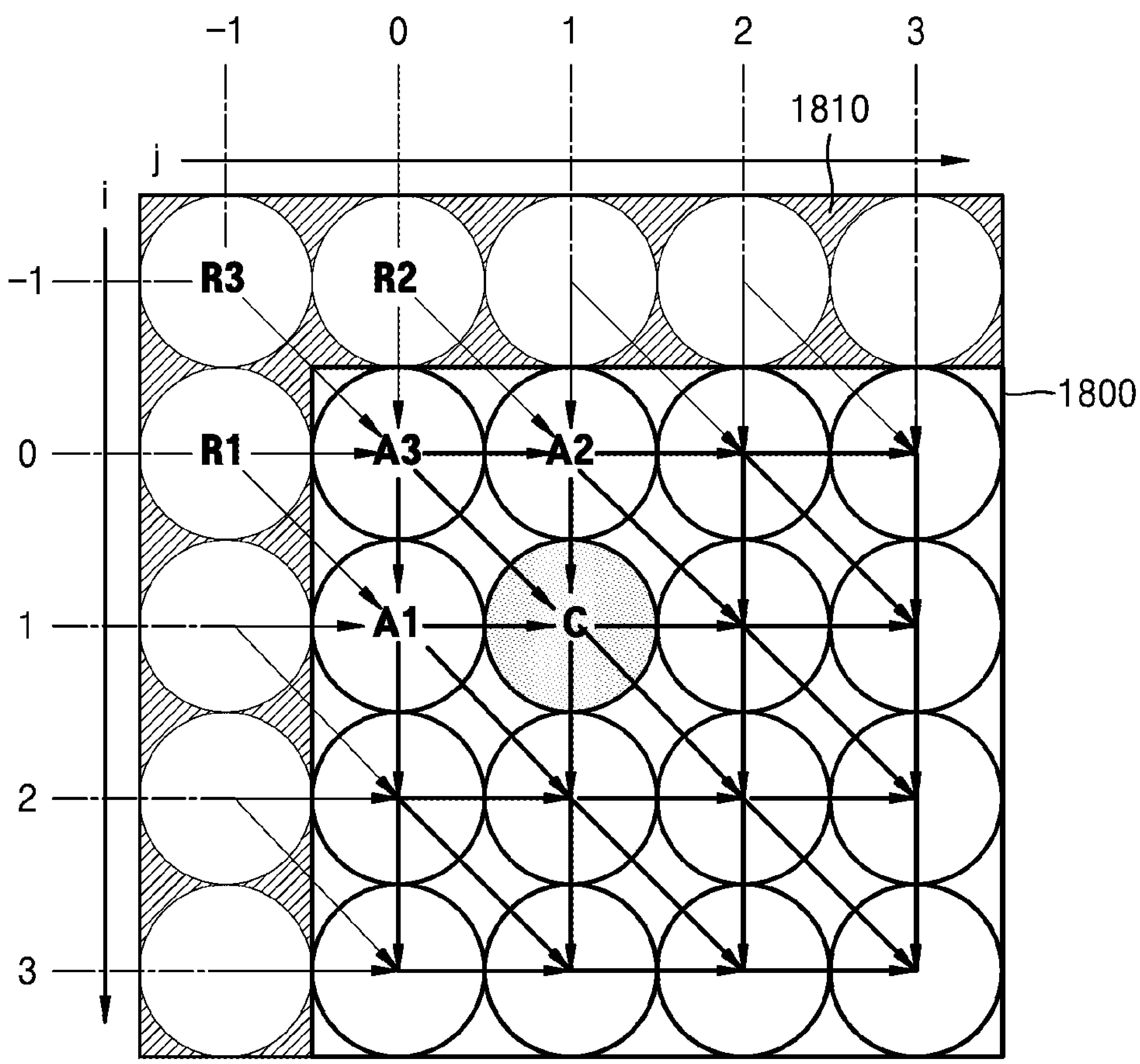


FIG. 18B

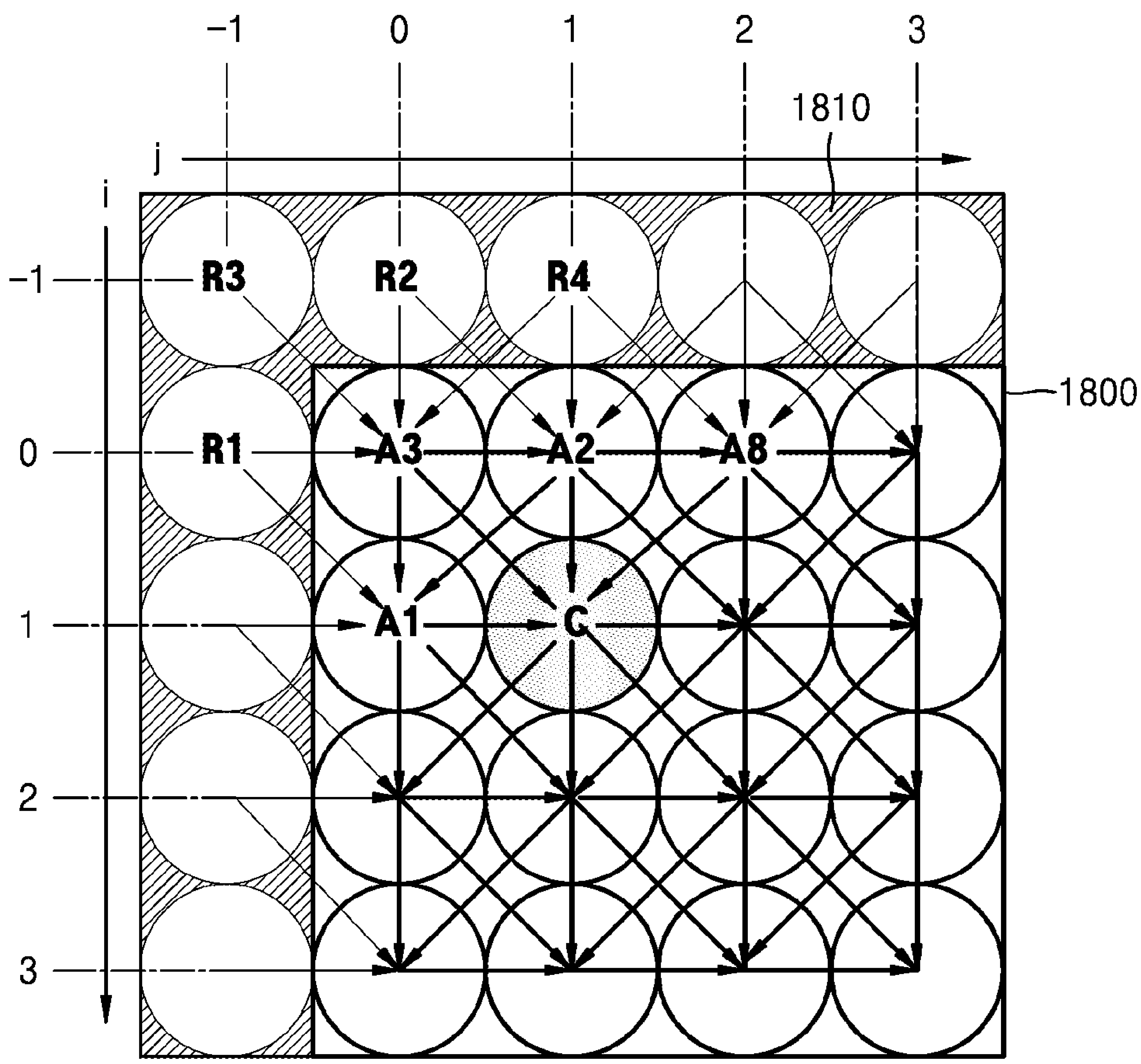


FIG. 19

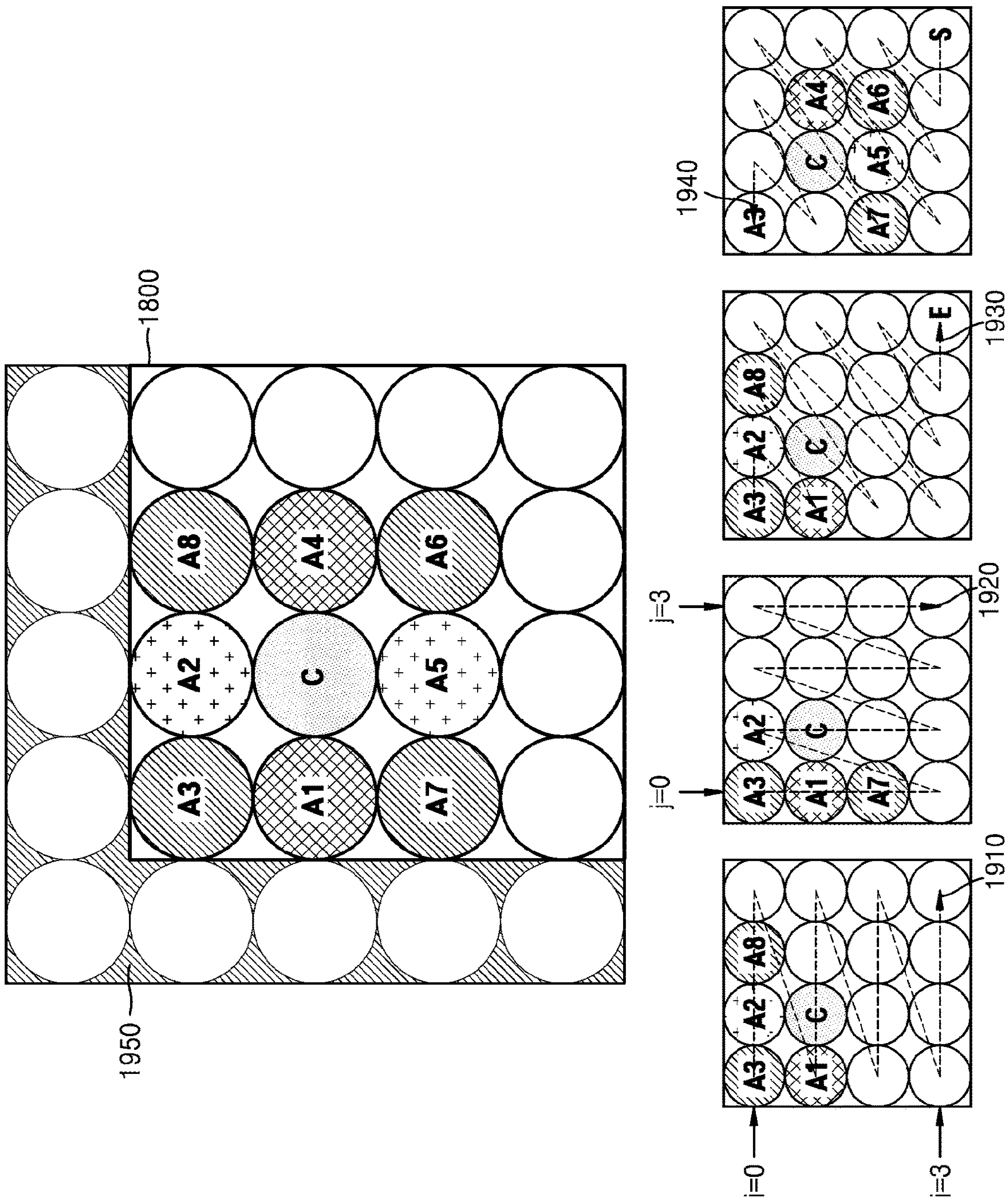

1800
1950
A1
A2
A3
A4
A5
A6
A7
A8
C
1910
1920
1930
1940
i=0
i=3
j=0
j=3
S
E

FIG. 20

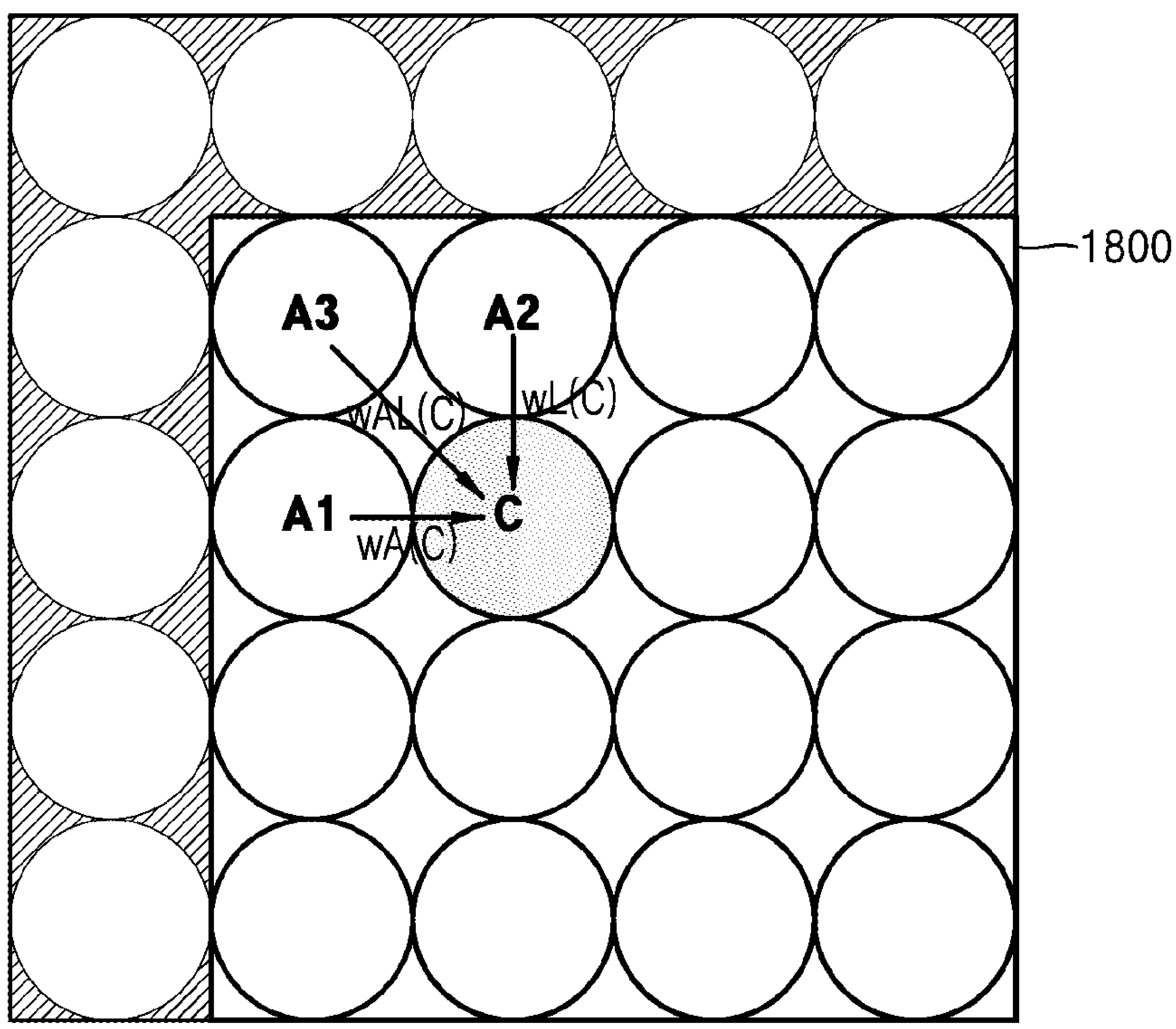


FIG. 21

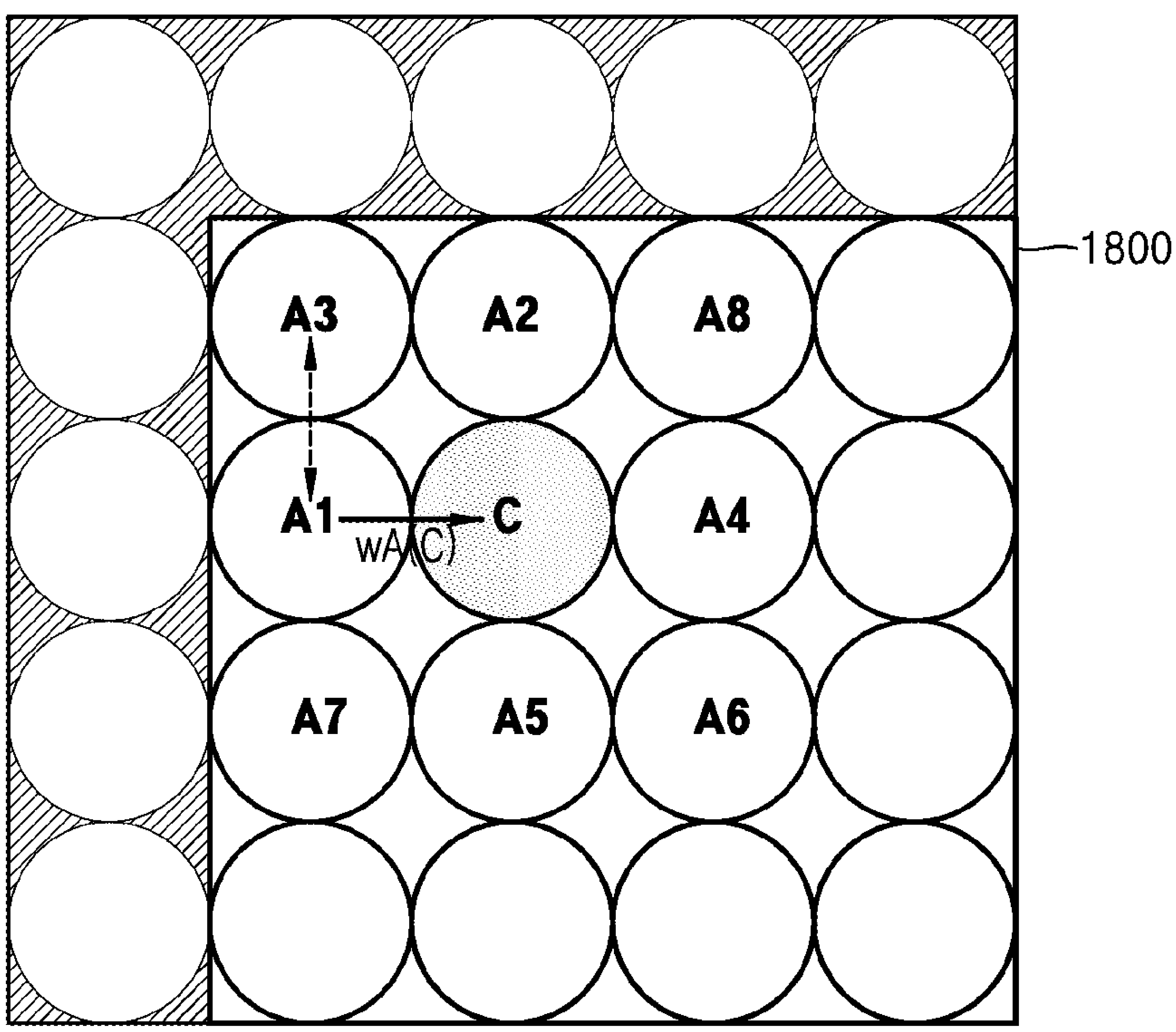


FIG. 22

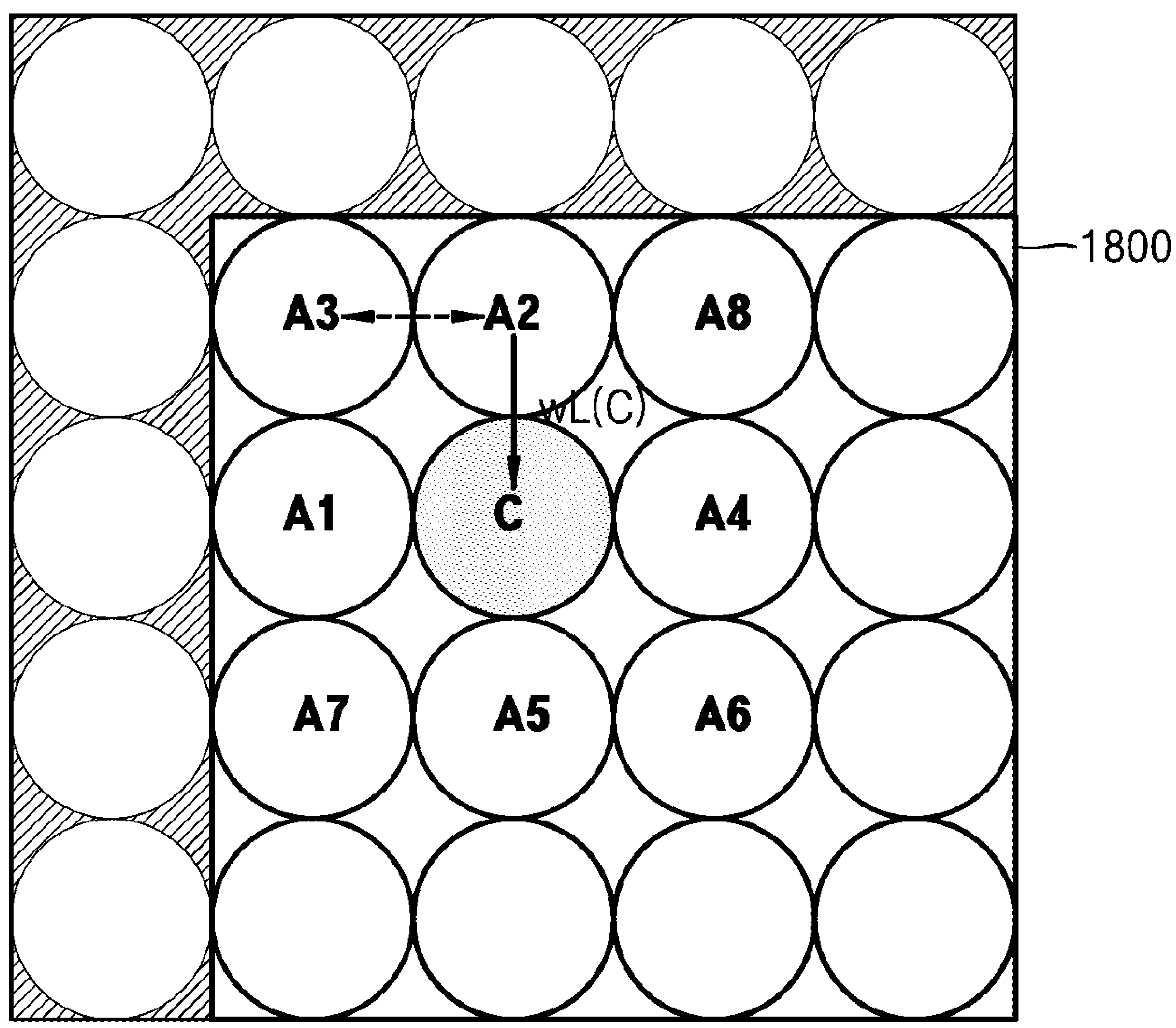


FIG. 23

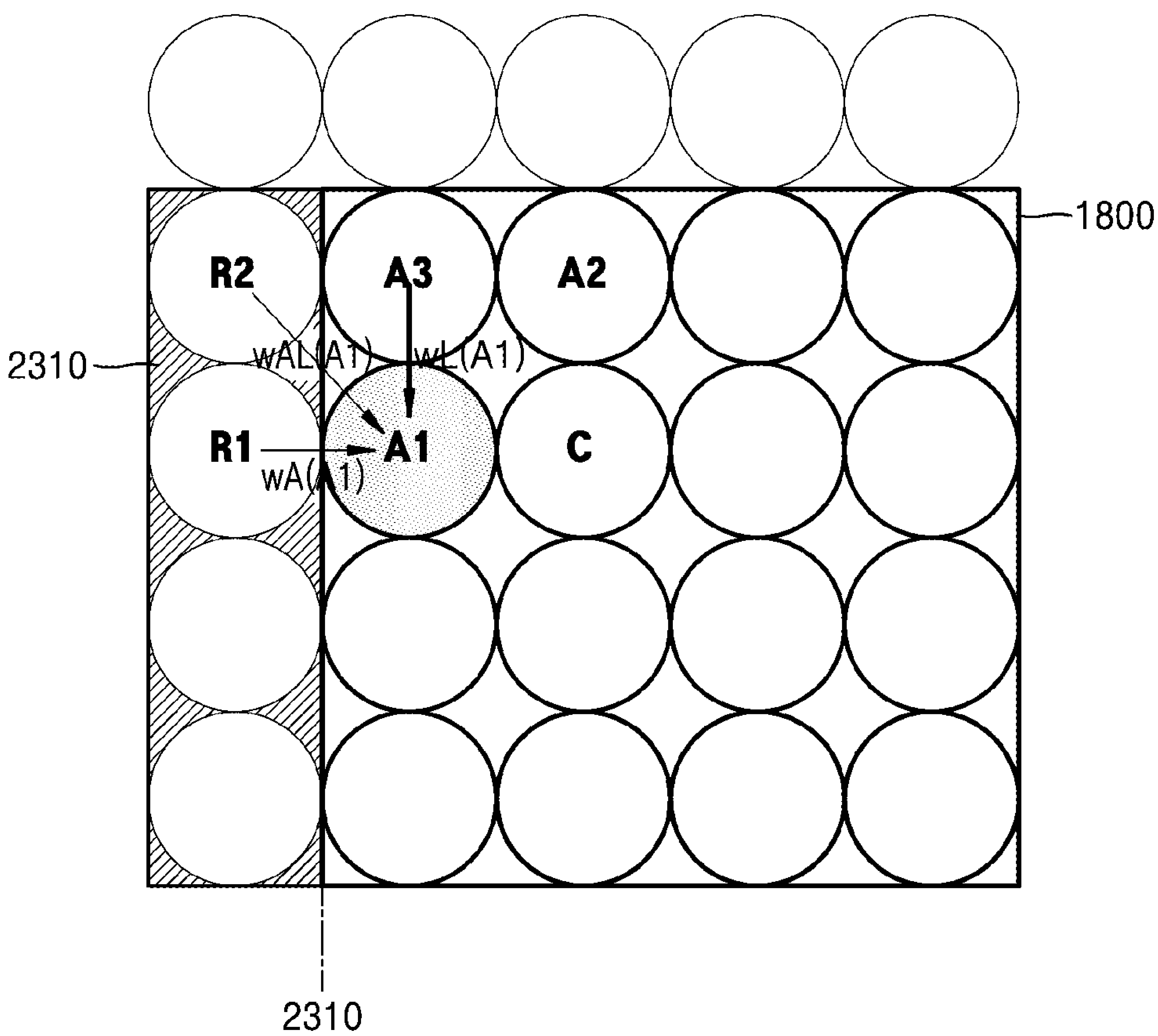


FIG. 24

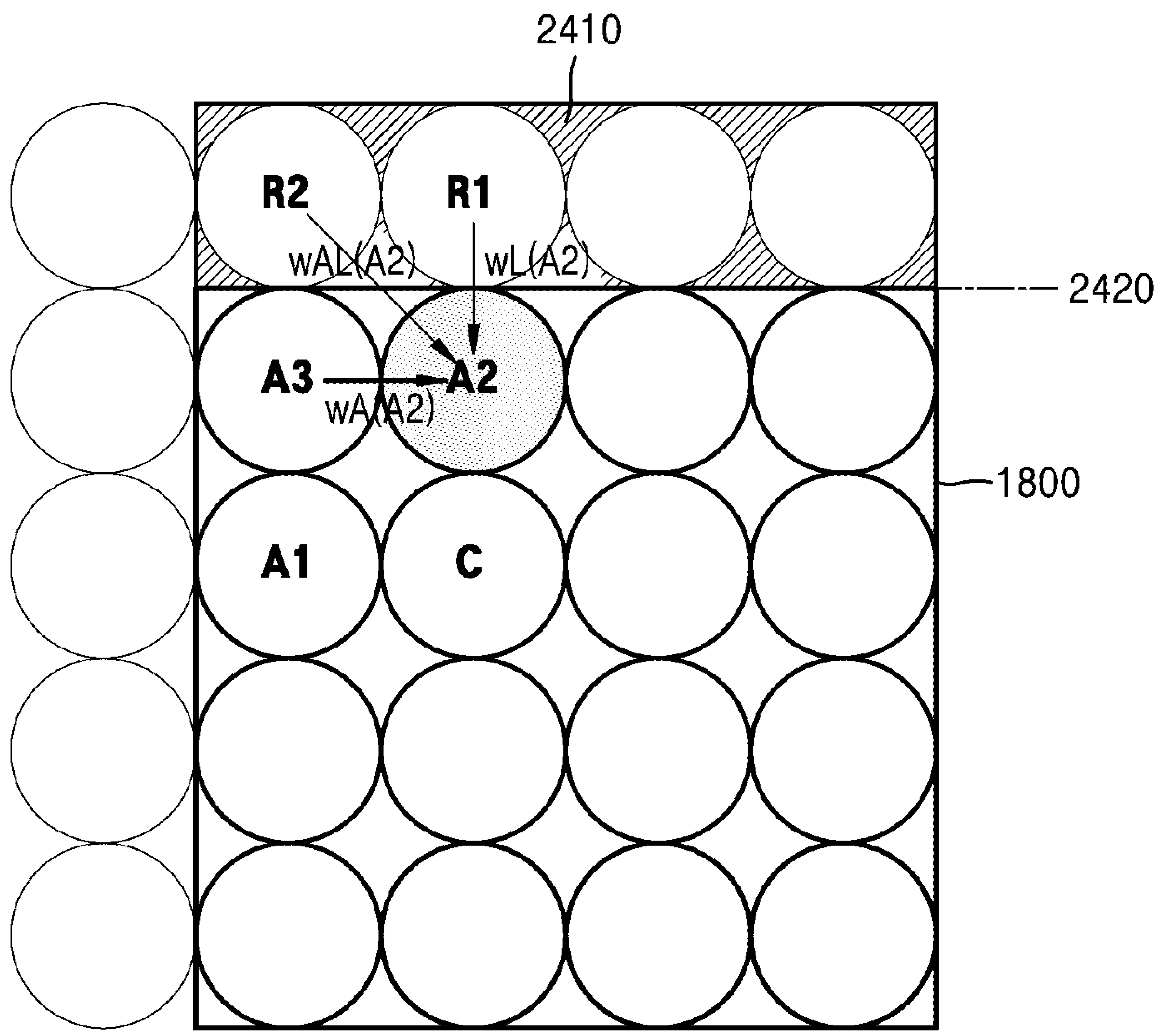


FIG. 25

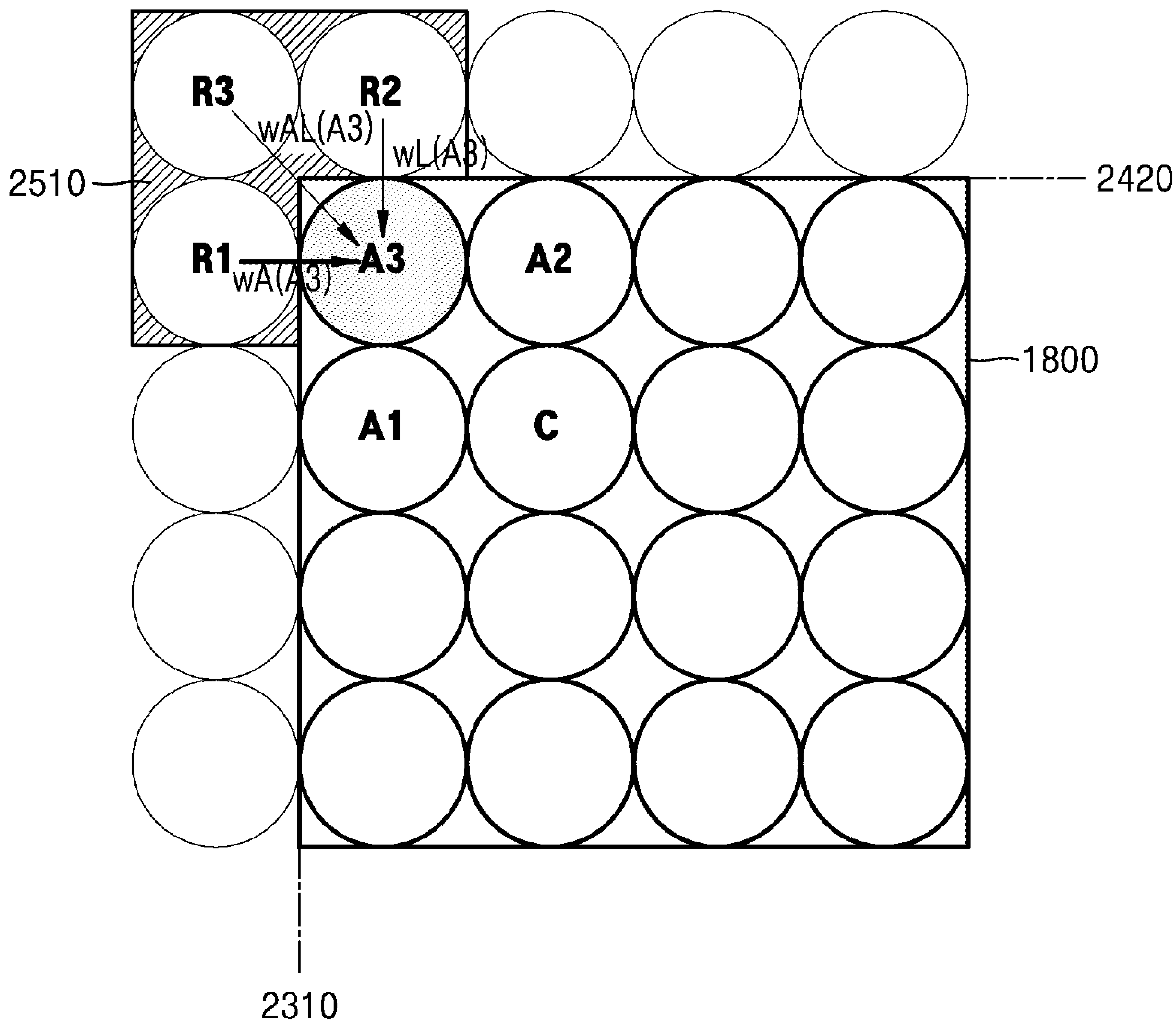


FIG. 26

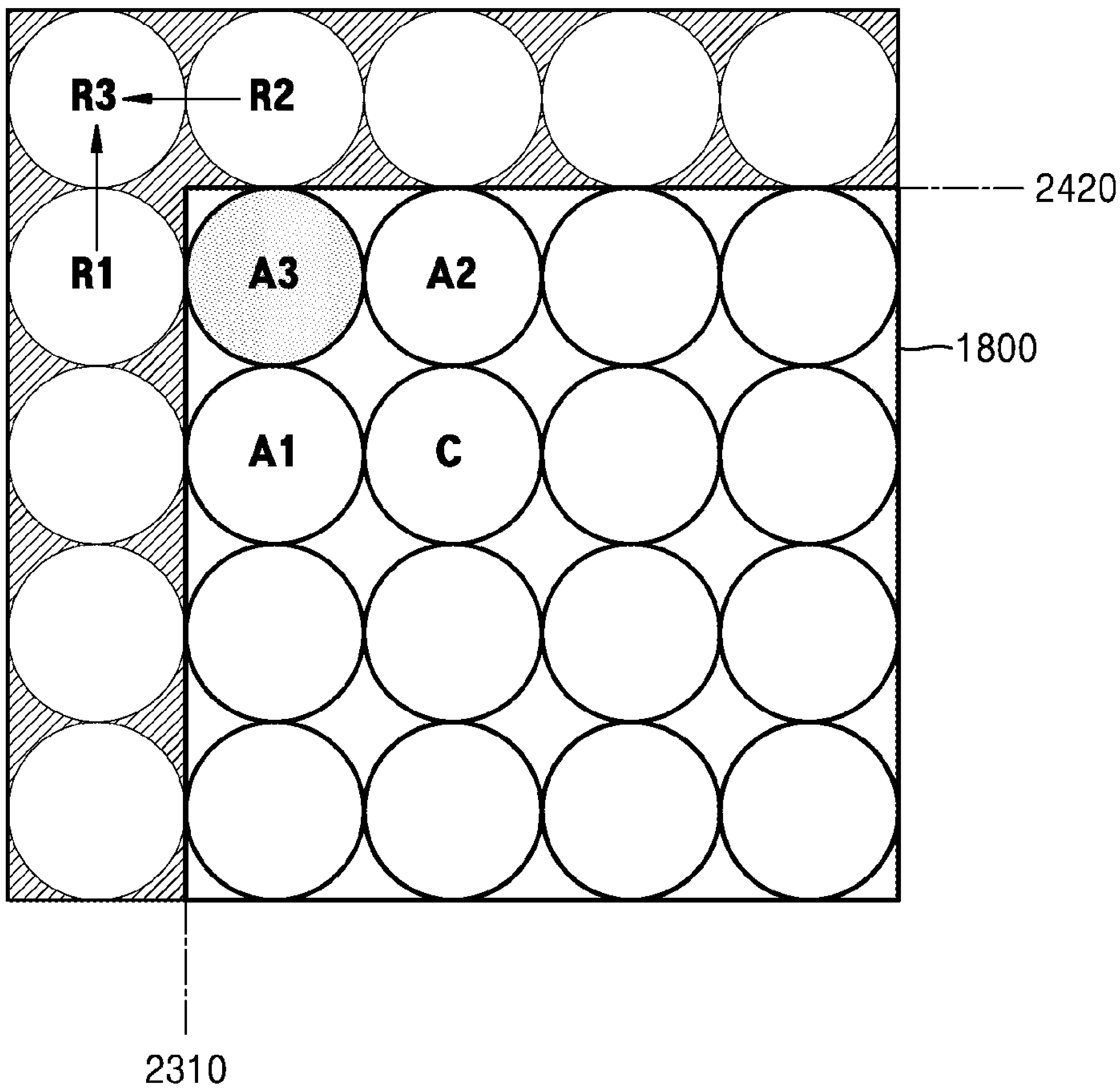


FIG. 27

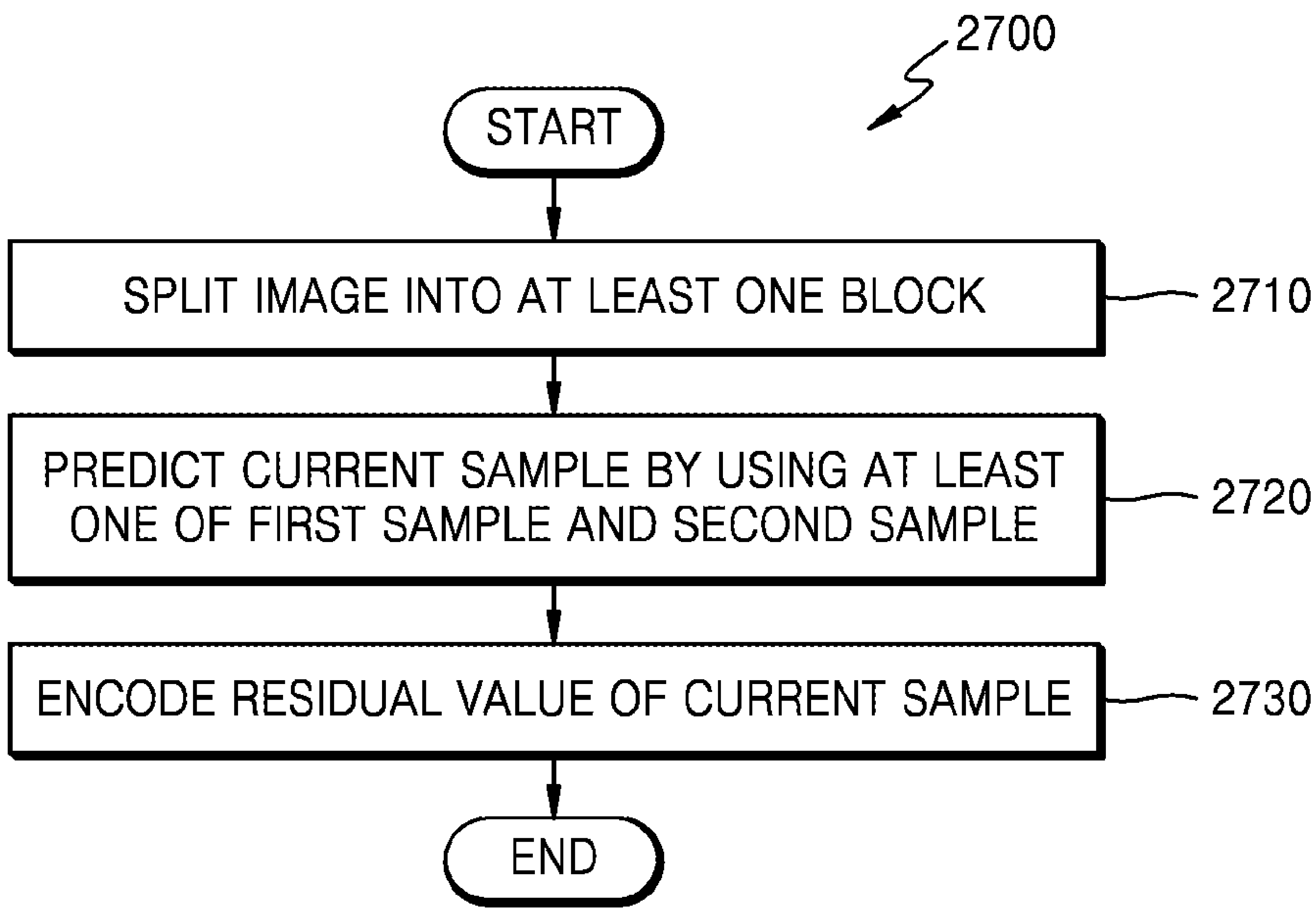

2700
START
SPLIT IMAGE INTO AT LEAST ONE BLOCK
2710
PREDICT CURRENT SAMPLE BY USING AT LEAST ONE OF FIRST SAMPLE AND SECOND SAMPLE
2720
ENCODE RESIDUAL VALUE OF CURRENT SAMPLE
2730
END

FIG. 28

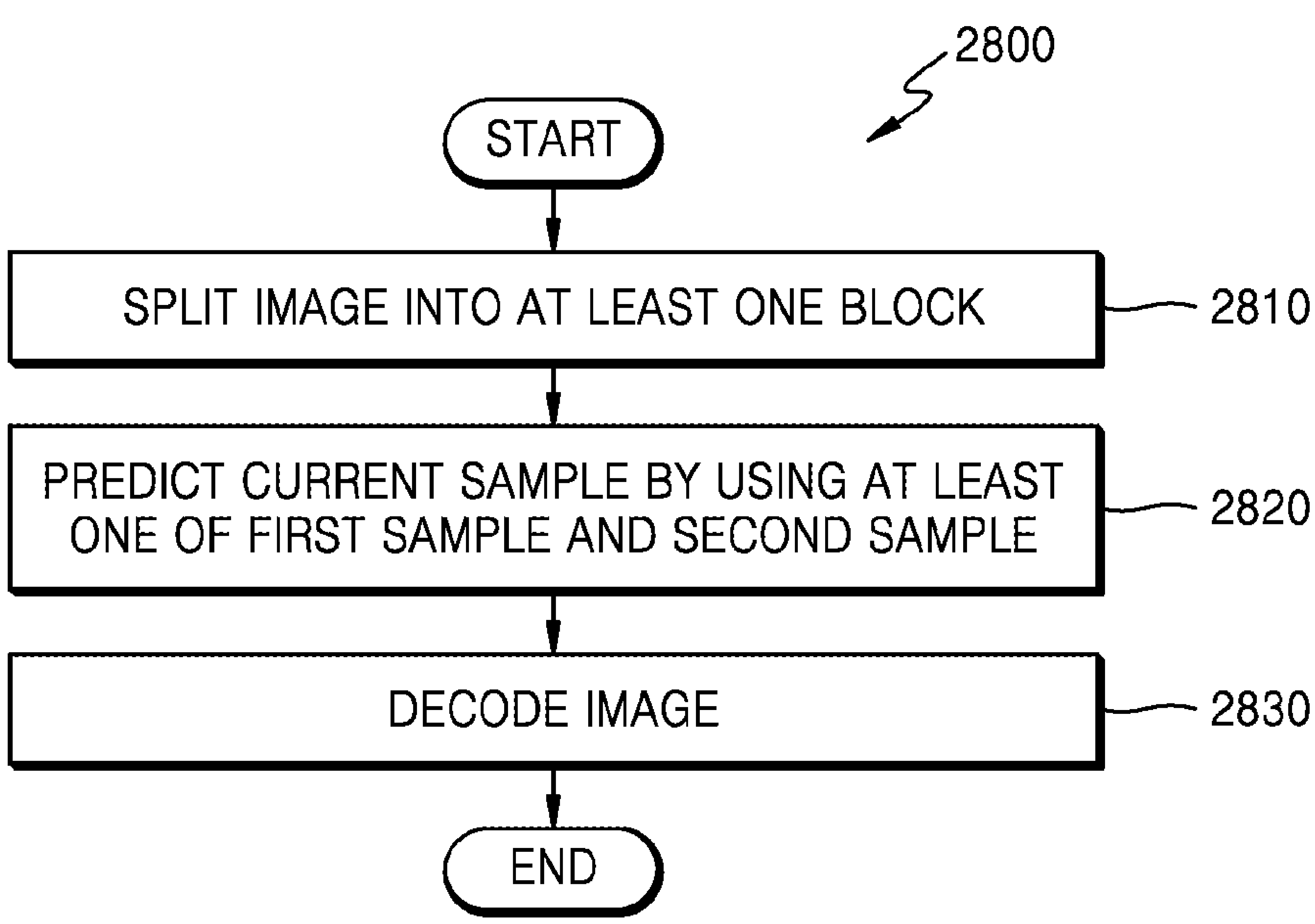

2800
START
SPLIT IMAGE INTO AT LEAST ONE BLOCK
2810
PREDICT CURRENT SAMPLE BY USING AT LEAST ONE OF FIRST SAMPLE AND SECOND SAMPLE
2820
DECODE IMAGE
2830
END

FIG. 29

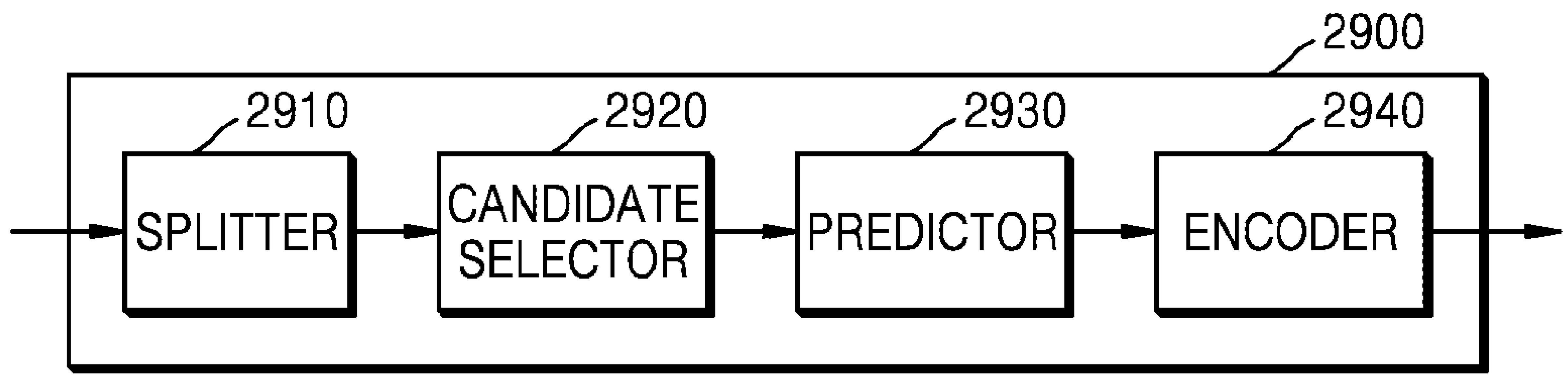

2900
2910
2920
2930
2940
SPLITTER
CANDIDATE SELECTOR
PREDICTOR
ENCODER

FIG. 30

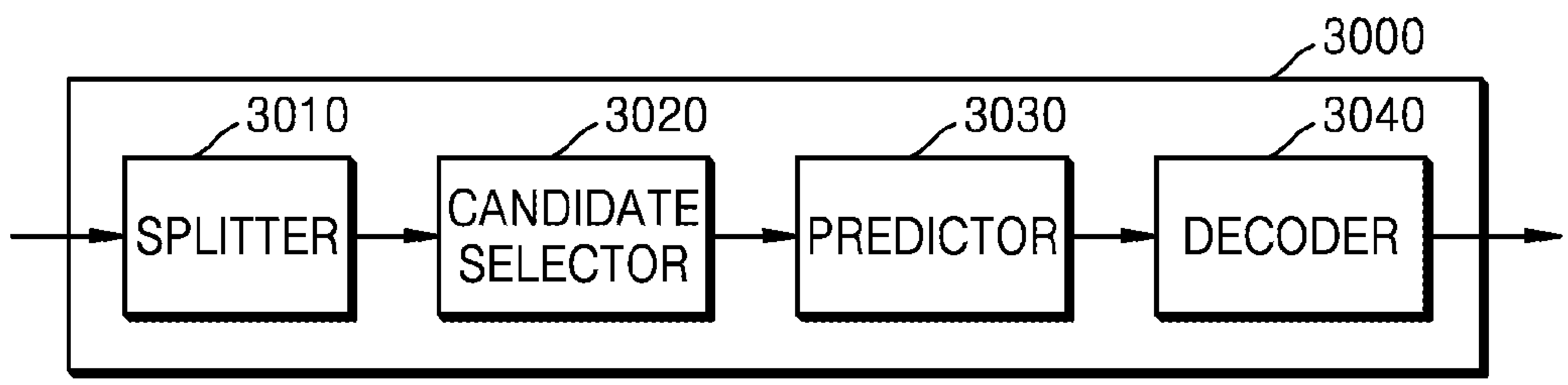
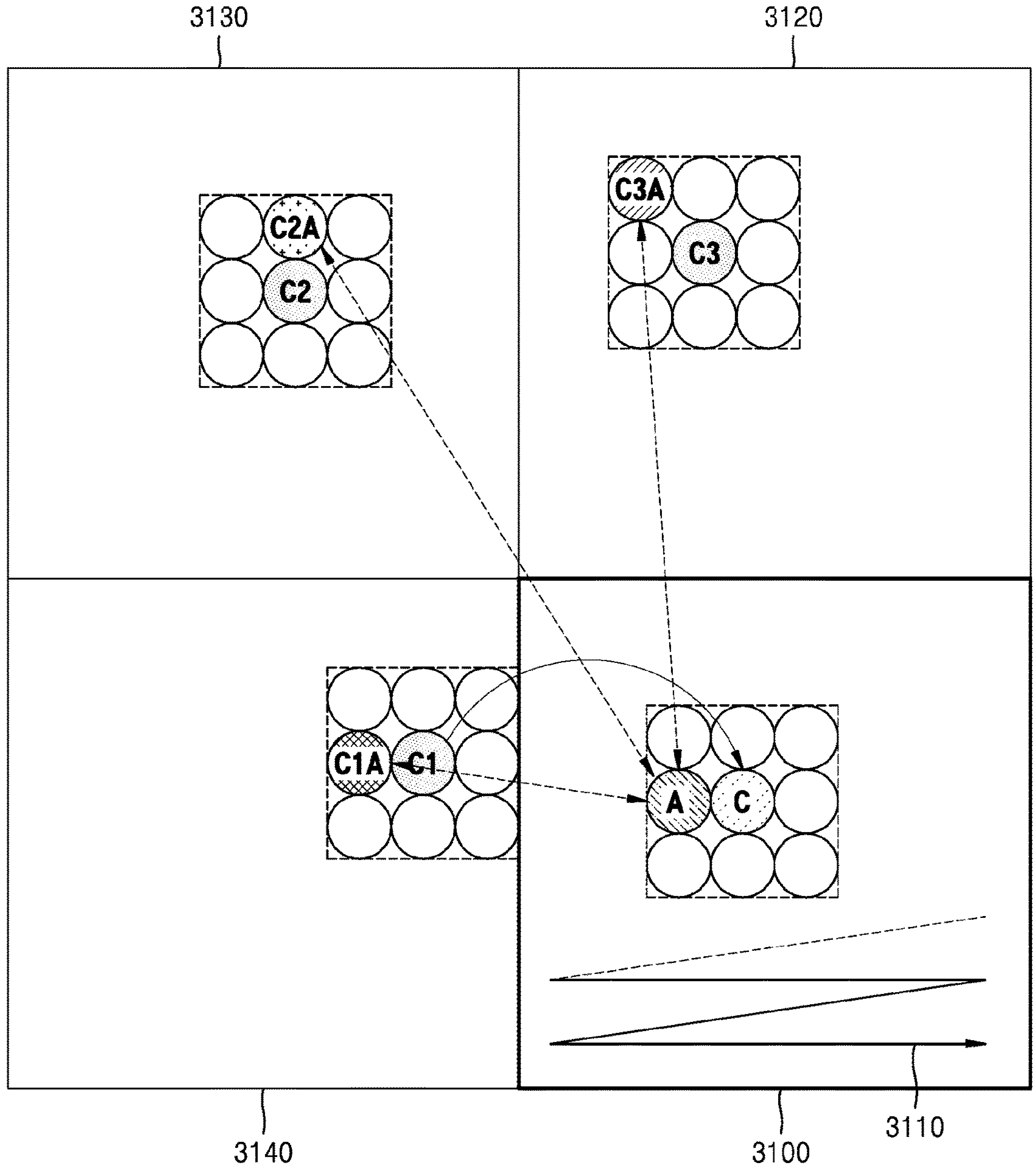

3000
3010
3020
3030
3040
SPLITTER
CANDIDATE SELECTOR
PREDICTOR
DECODER

FIG. 31



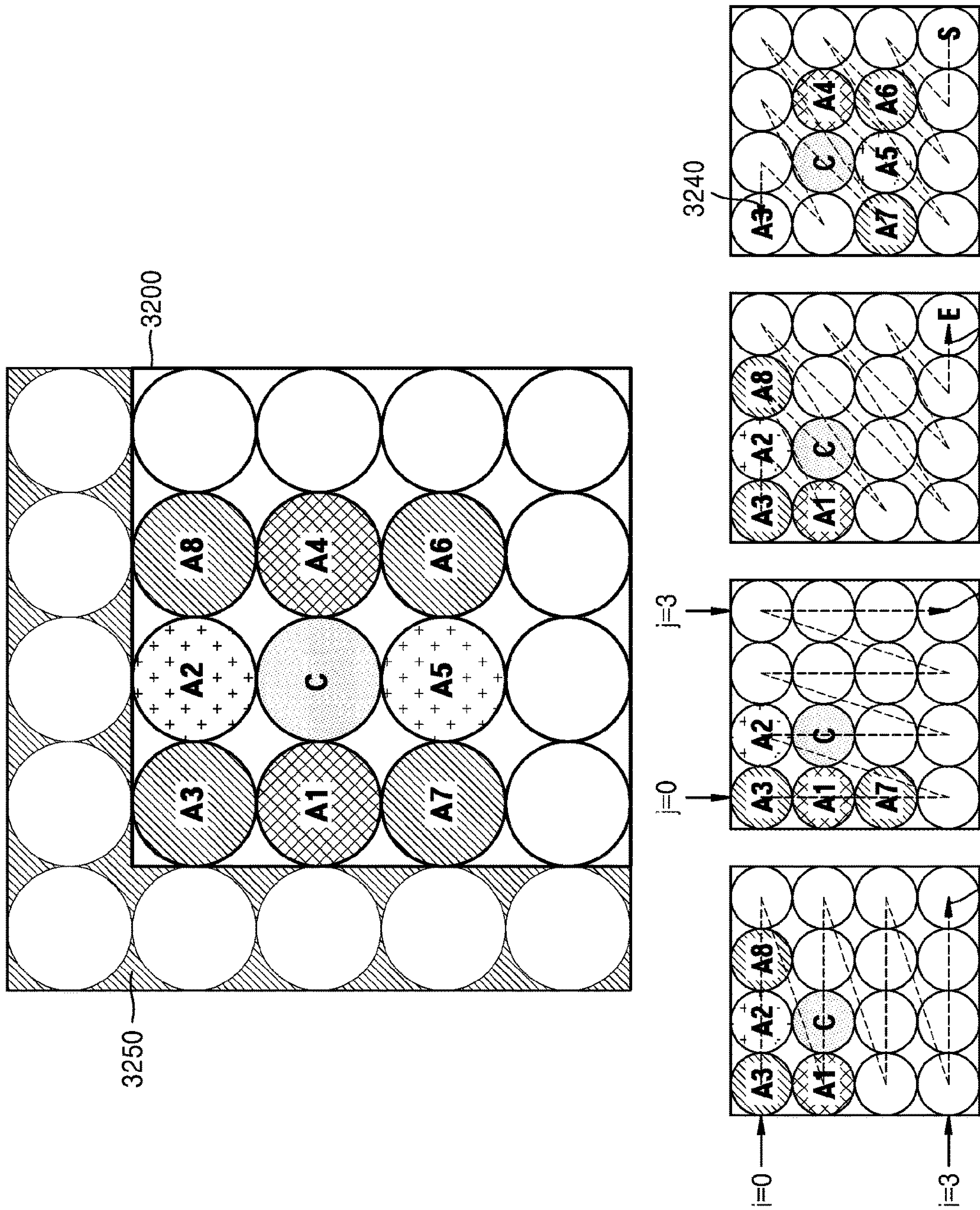

3200
3250
A3
A1
A7
A2
C
A5
A8
A4
A6
3210
3220
3230
3240
i=0
i=3
j=0
j=3
S
E

FIG. 32

FIG. 33

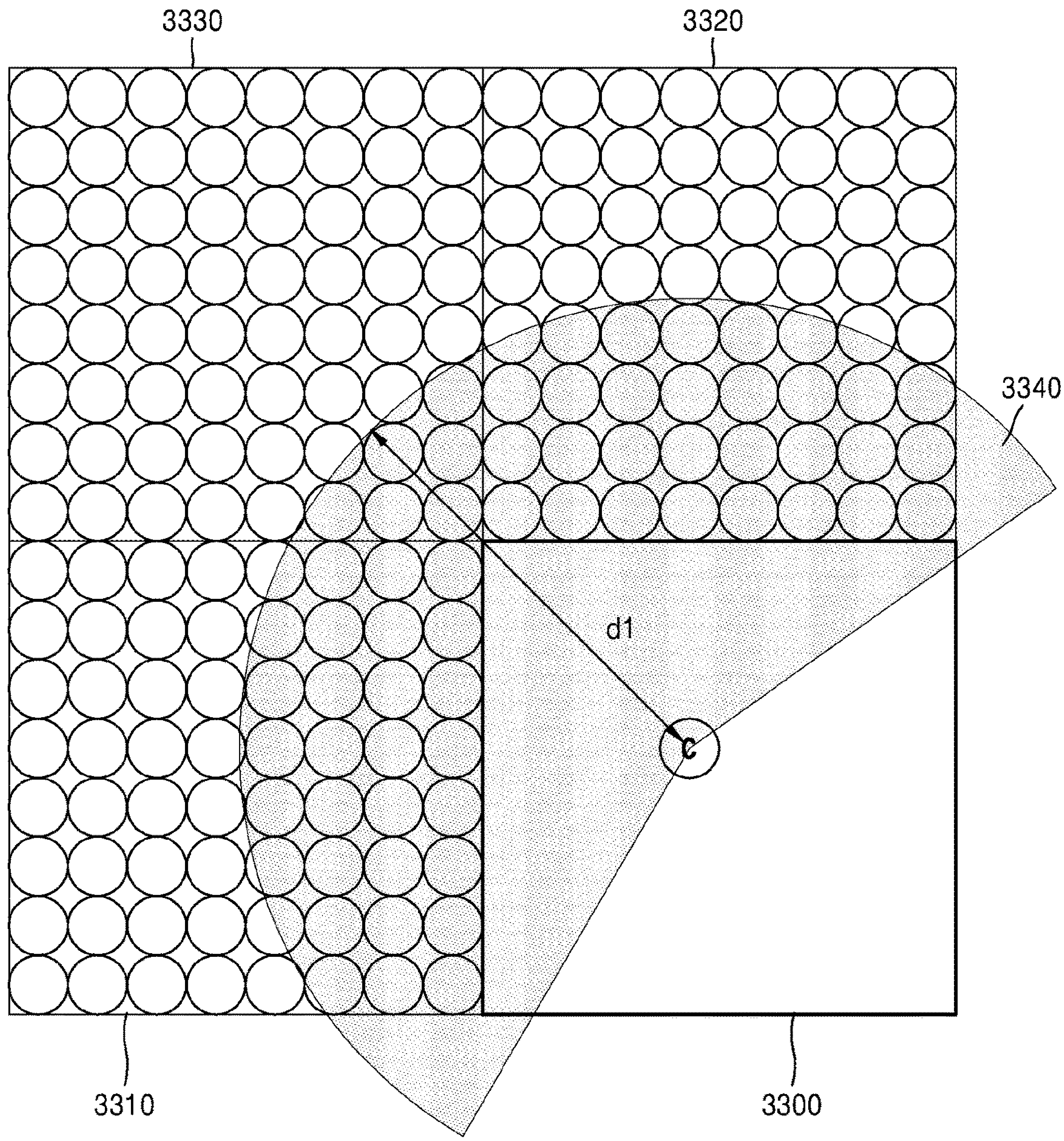


FIG. 34

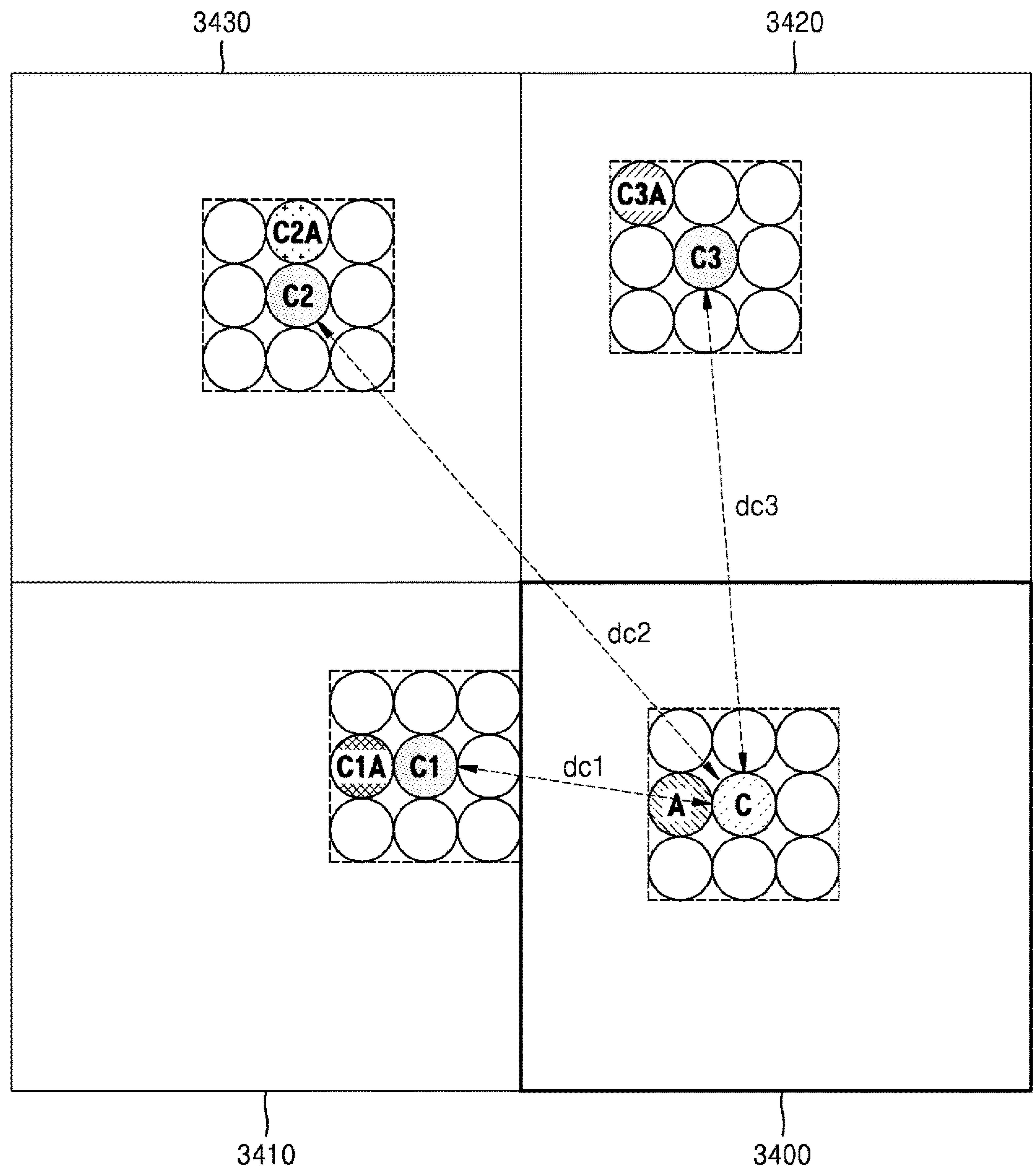


FIG. 35

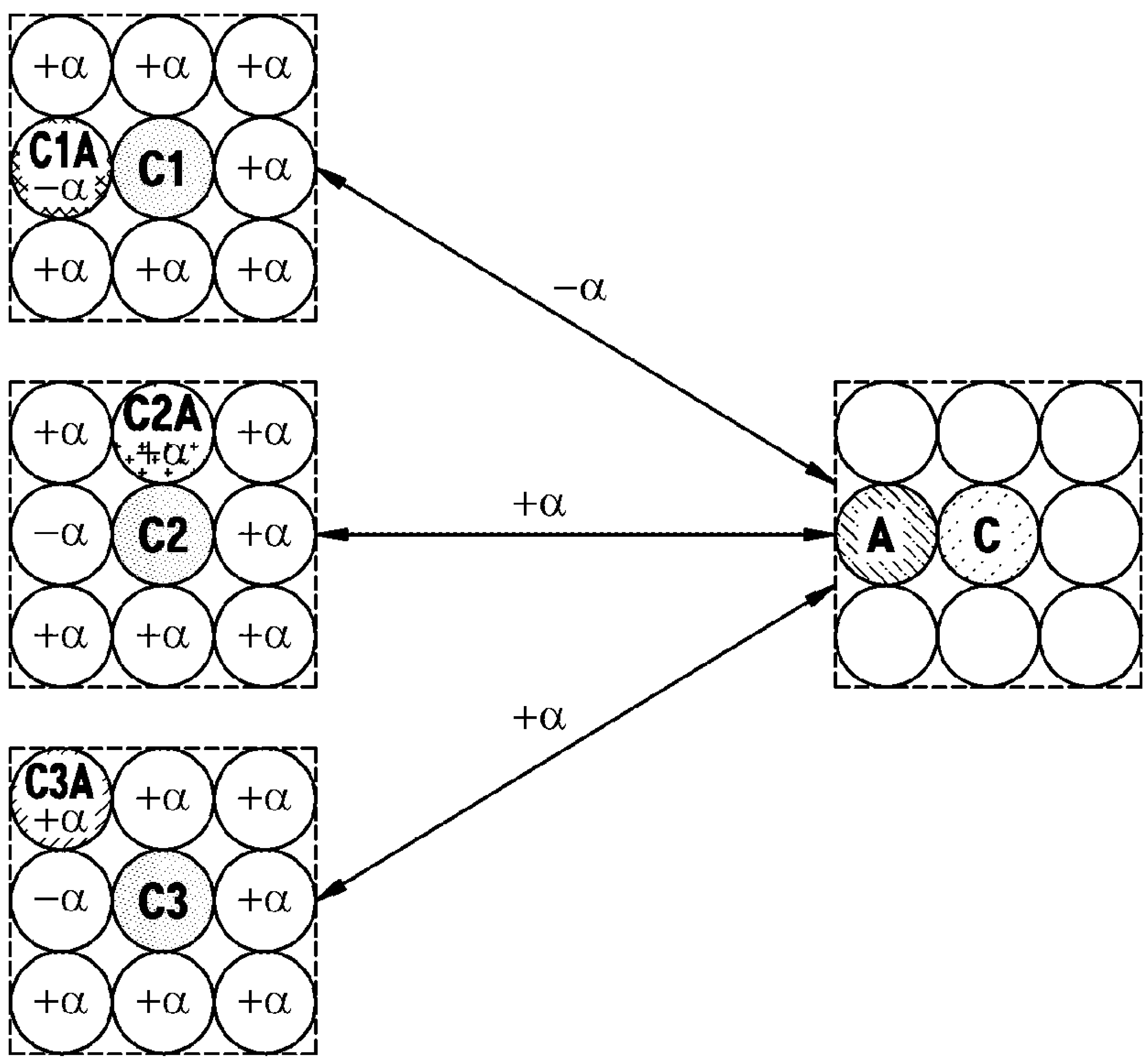


FIG. 36

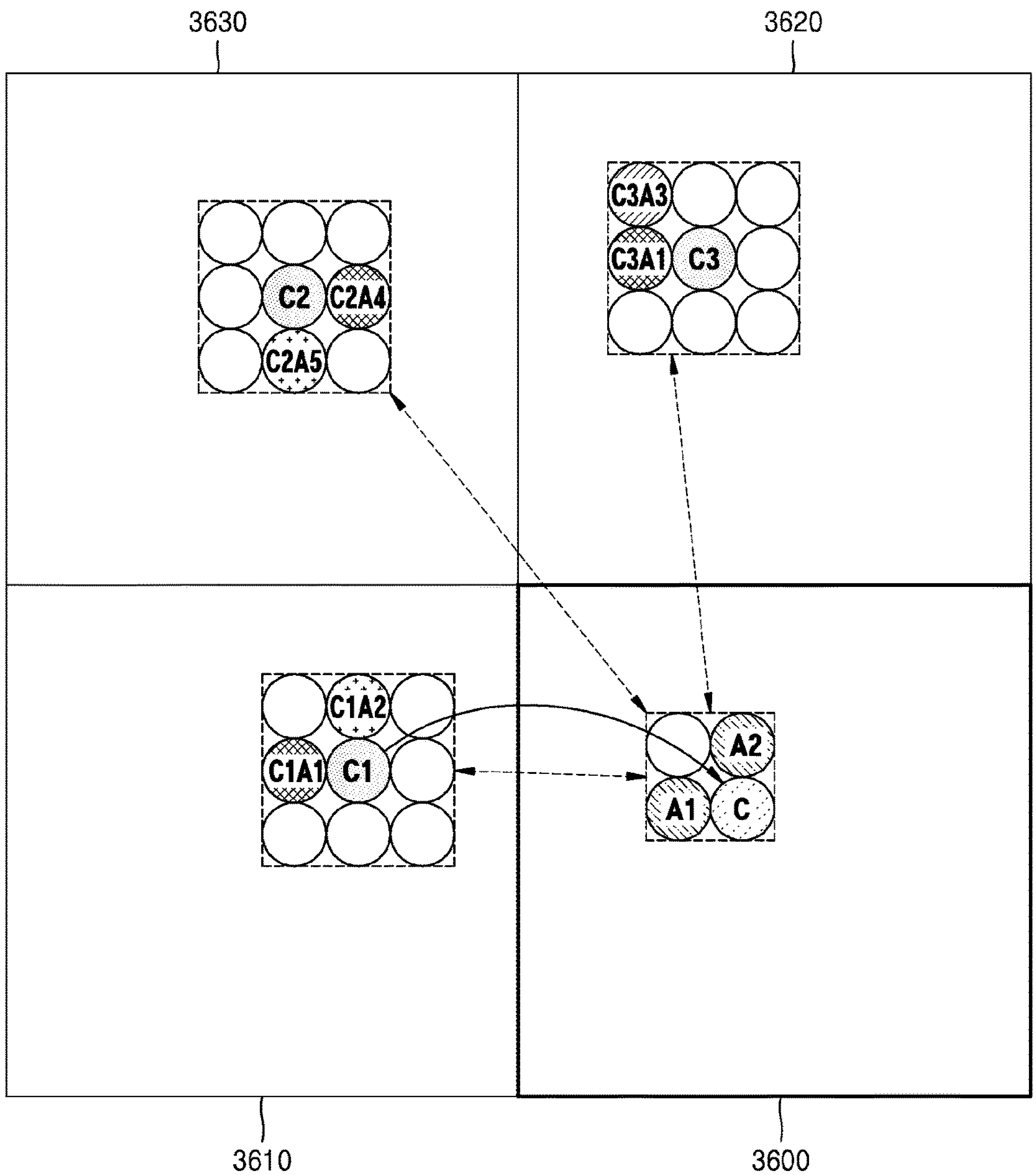

3630
3620
C3A3
C3A1
C3
C2
C2A4
C2A5
C1A2
C1A1
C1
A2
A1
C
3610
3600

FIG. 37

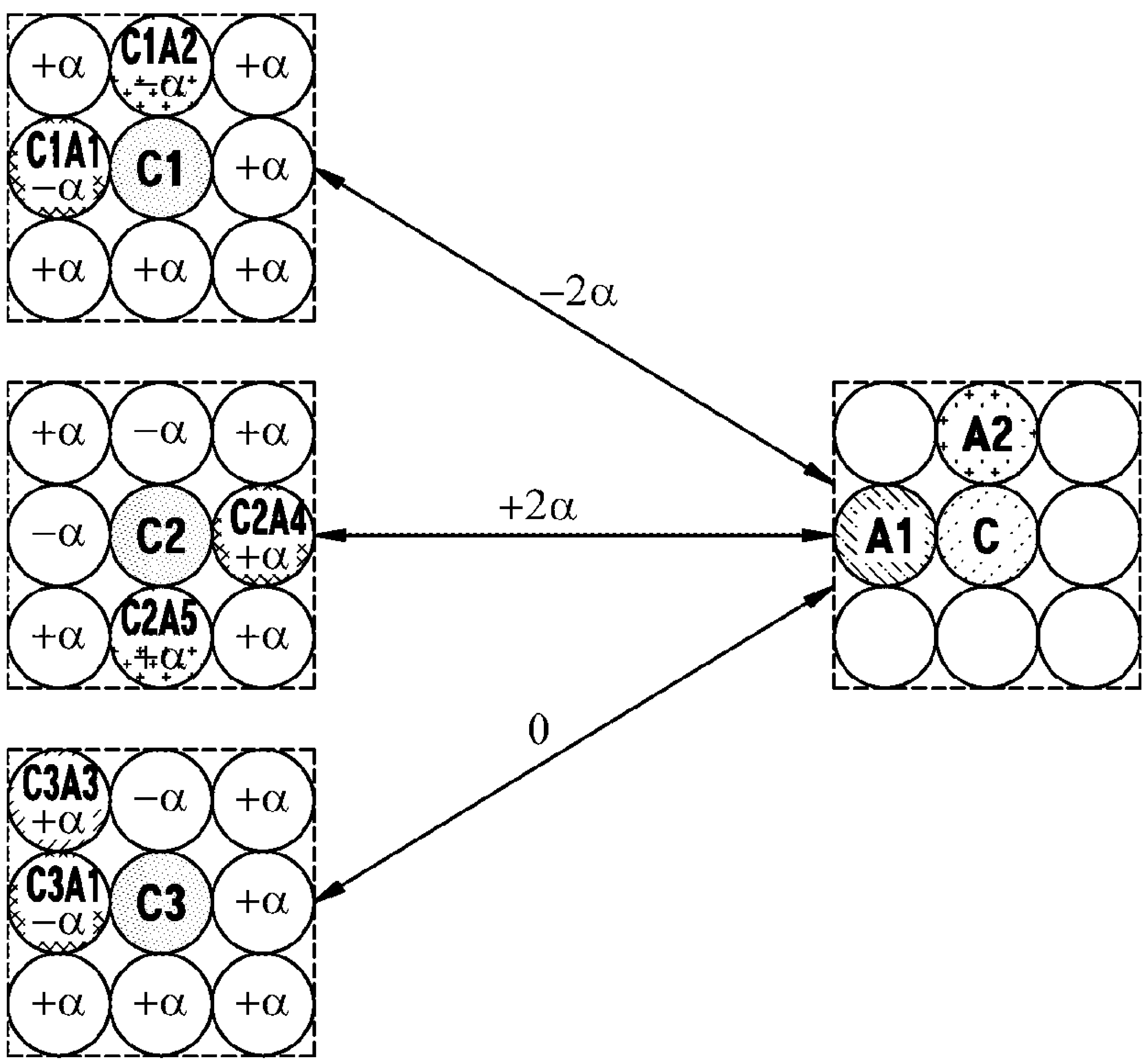

+α
C1A2
+α
+α
C1A1
−α
C1
+α
+α
+α
+α
−2α
+α
−α
+α
−α
C2
C2A4
+α
+2α
+α
C2A5
+α
+α
0
C3A3
+α
−α
+α
C3A1
−α
C3
+α
+α
+α
+α
A2
A1
C

FIG. 38

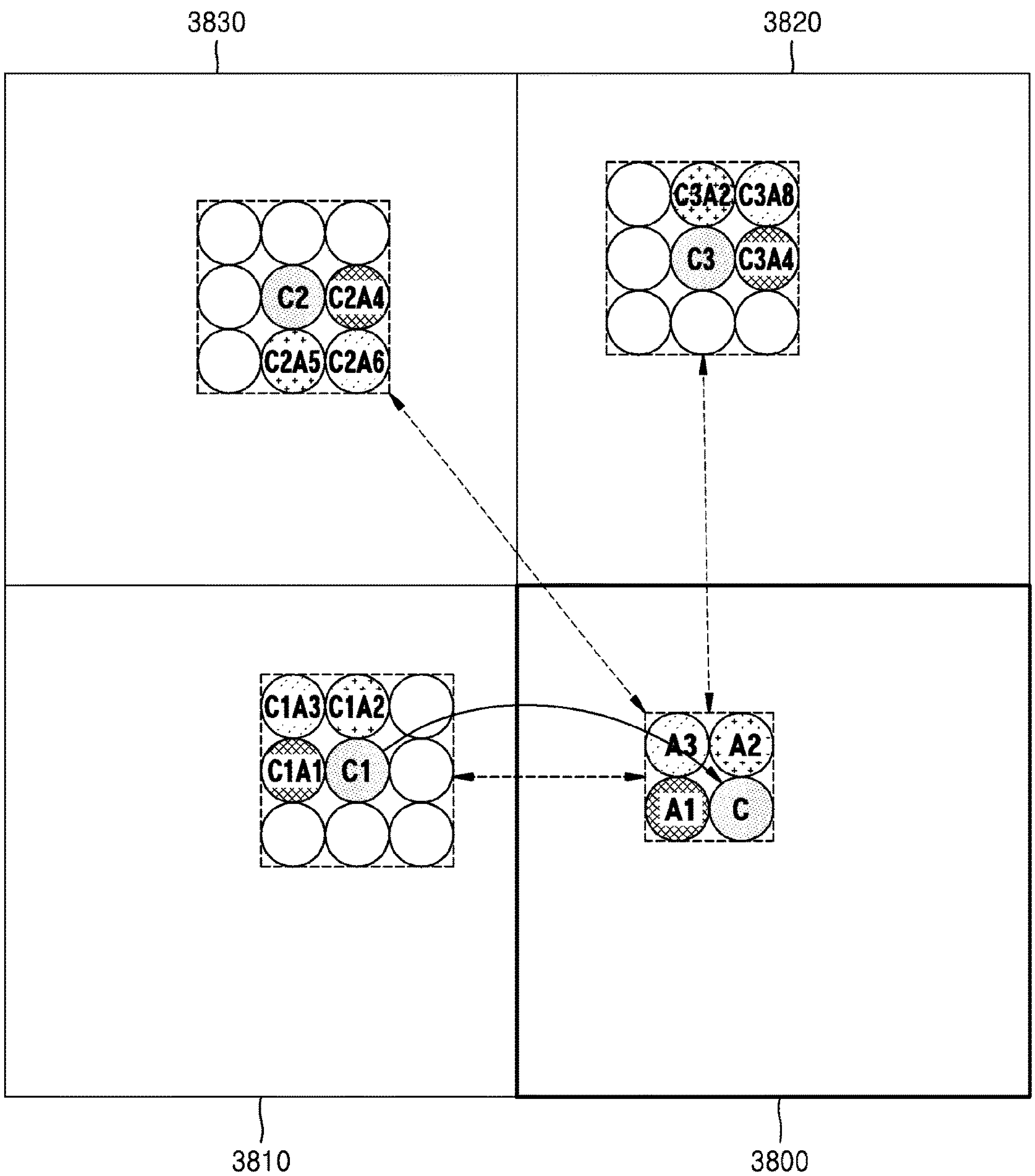

3830
3820
C3A2
C3A8
C3
C3A4
C2
C2A4
C2A5
C2A6
C1A3
C1A2
C1A1
C1
A3
A2
A1
C
3810
3800

FIG. 39

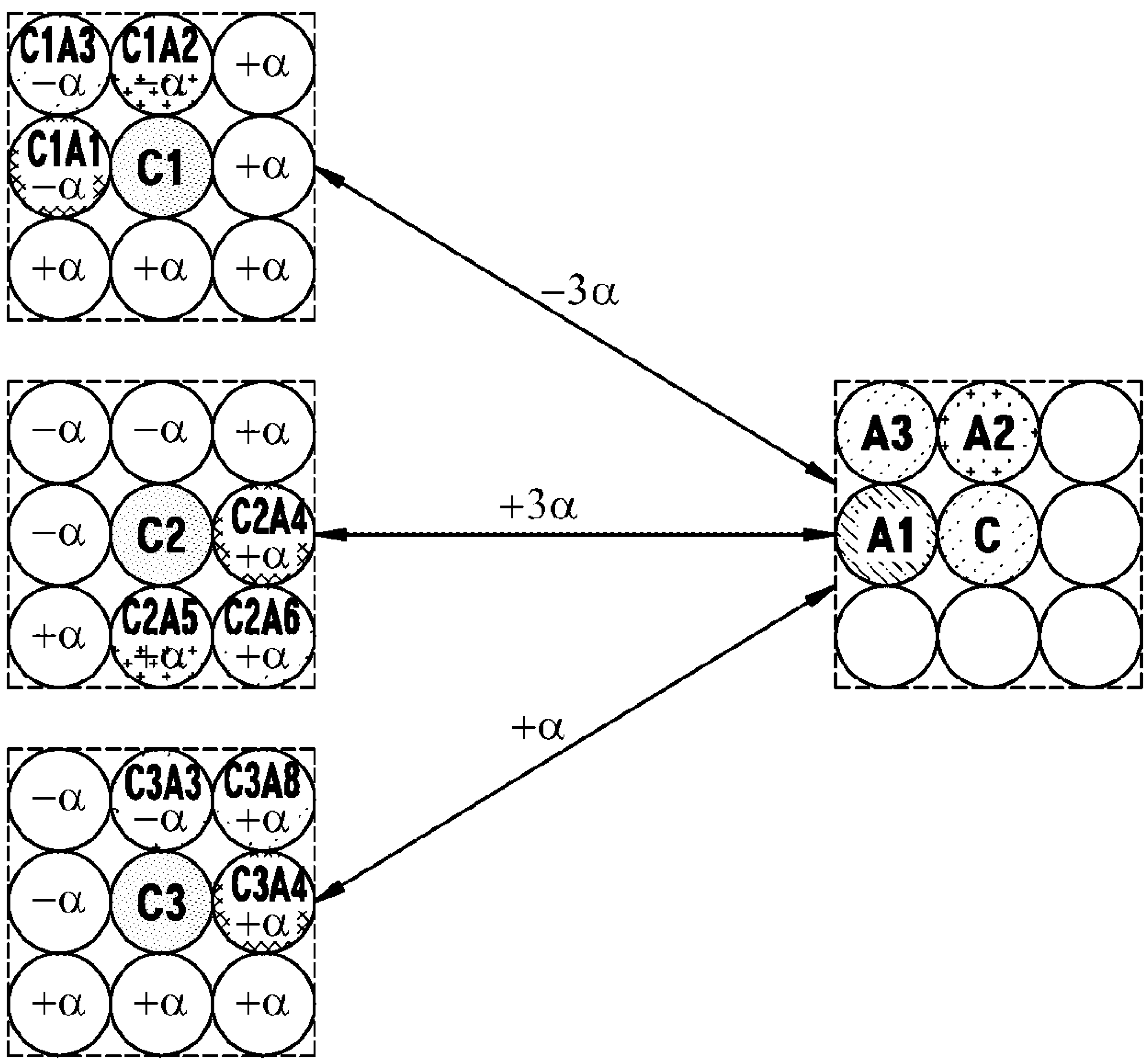

C1A3
−α
C1A2
+α
+α
C1A1
−α
C1
+α
+α
+α
+α
−3α
−α
−α
+α
−α
C2
C2A4
+α
+α
C2A5
+α
C2A6
+α
+3α
A3
A2
A1
C
+α
−α
C3A3
−α
C3A8
+α
−α
C3
C3A4
+α
+α
+α
+α

FIG. 40

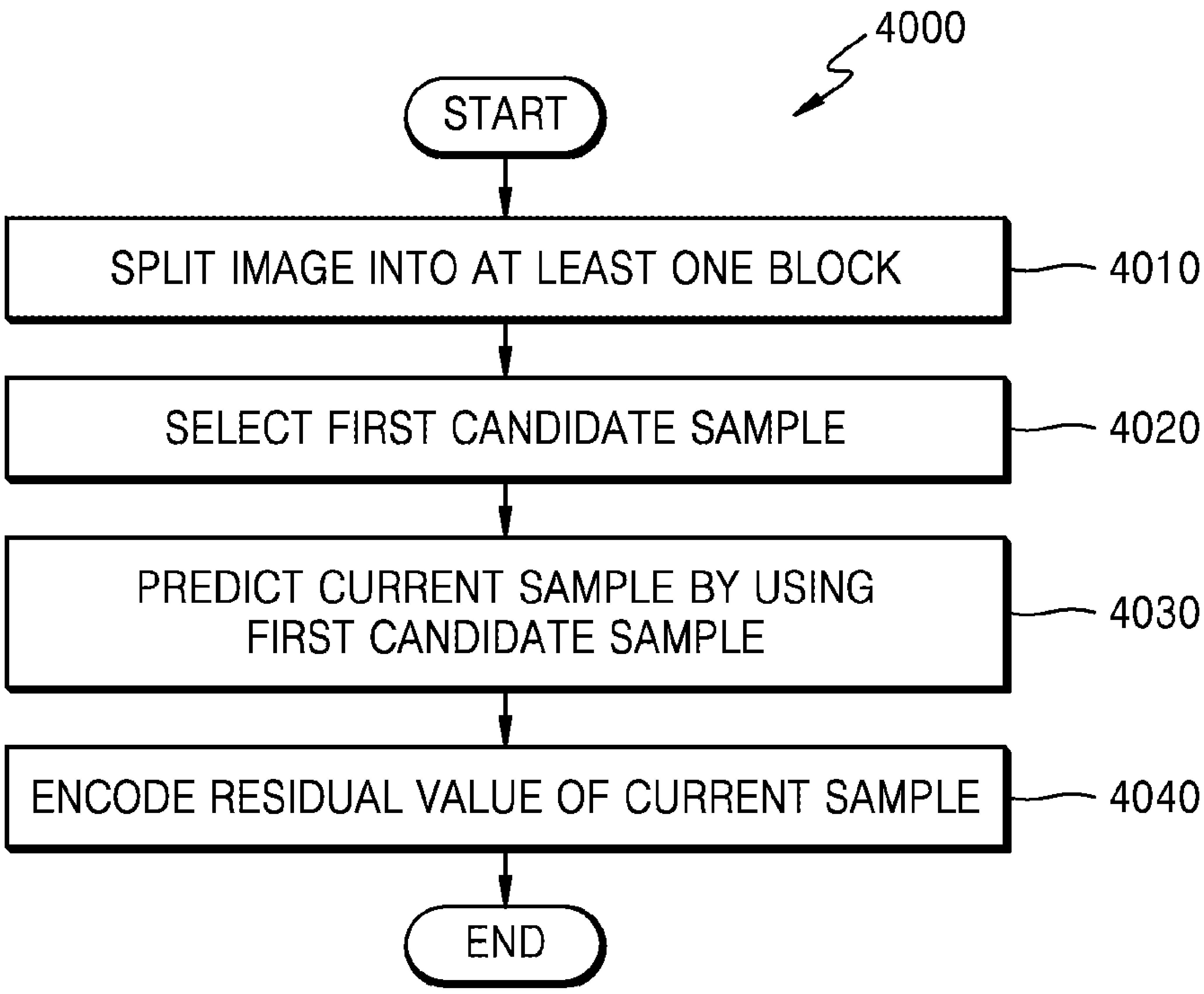

4000
START
SPLIT IMAGE INTO AT LEAST ONE BLOCK
4010
SELECT FIRST CANDIDATE SAMPLE
4020
PREDICT CURRENT SAMPLE BY USING FIRST CANDIDATE SAMPLE
4030
ENCODE RESIDUAL VALUE OF CURRENT SAMPLE
4040
END

FIG. 41

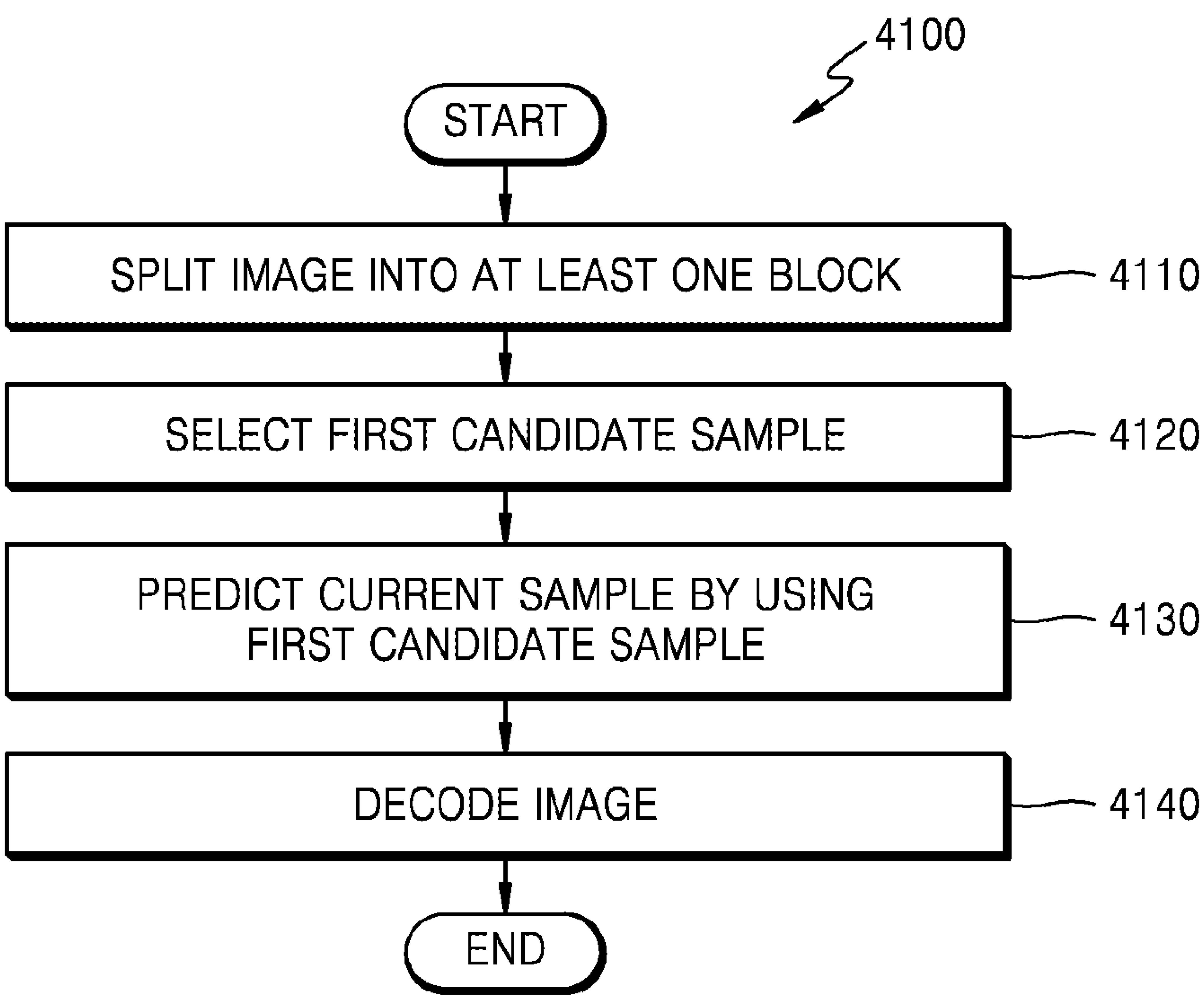

4100
START
SPLIT IMAGE INTO AT LEAST ONE BLOCK
4110
SELECT FIRST CANDIDATE SAMPLE
4120
PREDICT CURRENT SAMPLE BY USING FIRST CANDIDATE SAMPLE
4130
DECODE IMAGE
4140
END

FIG. 42

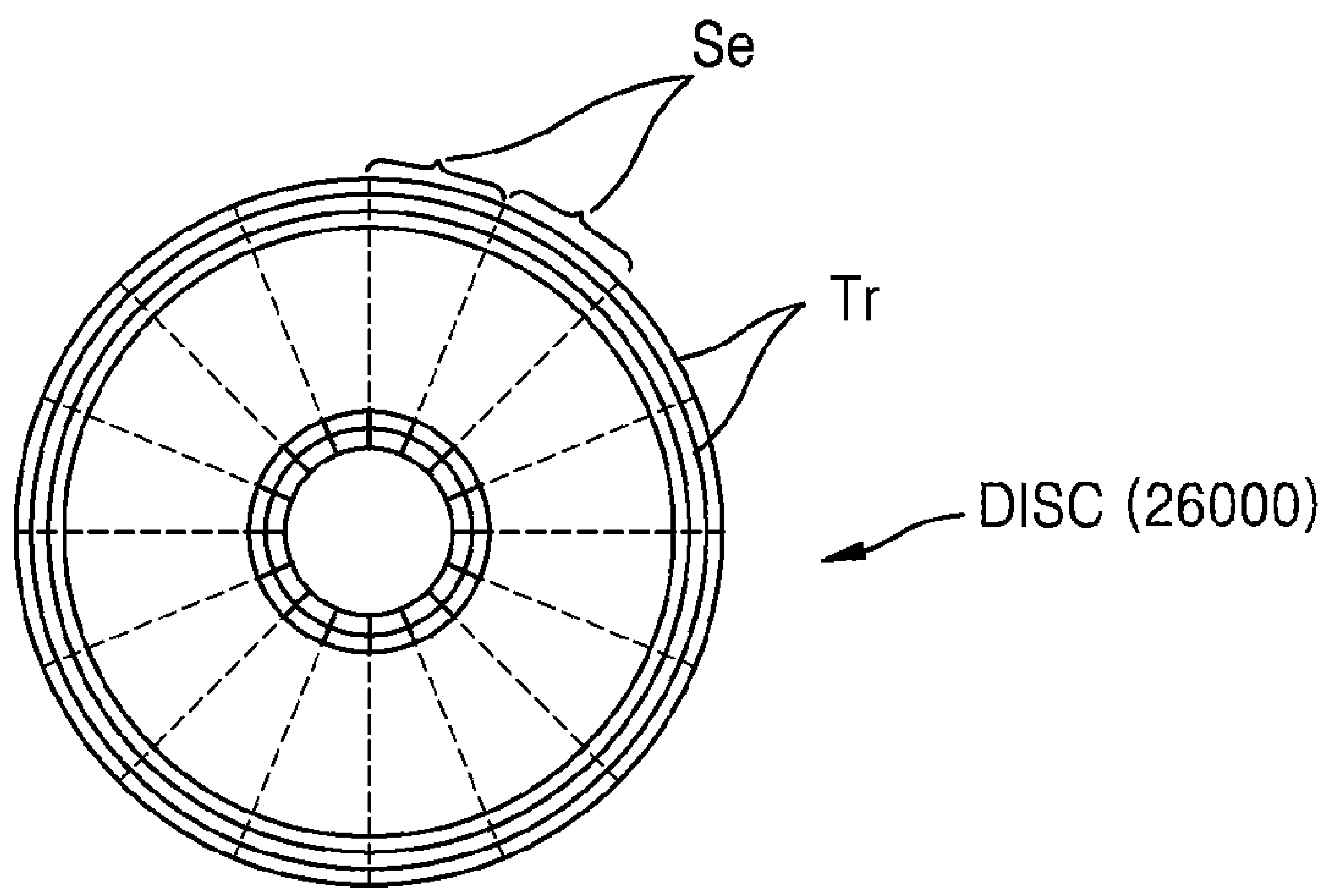


FIG. 43

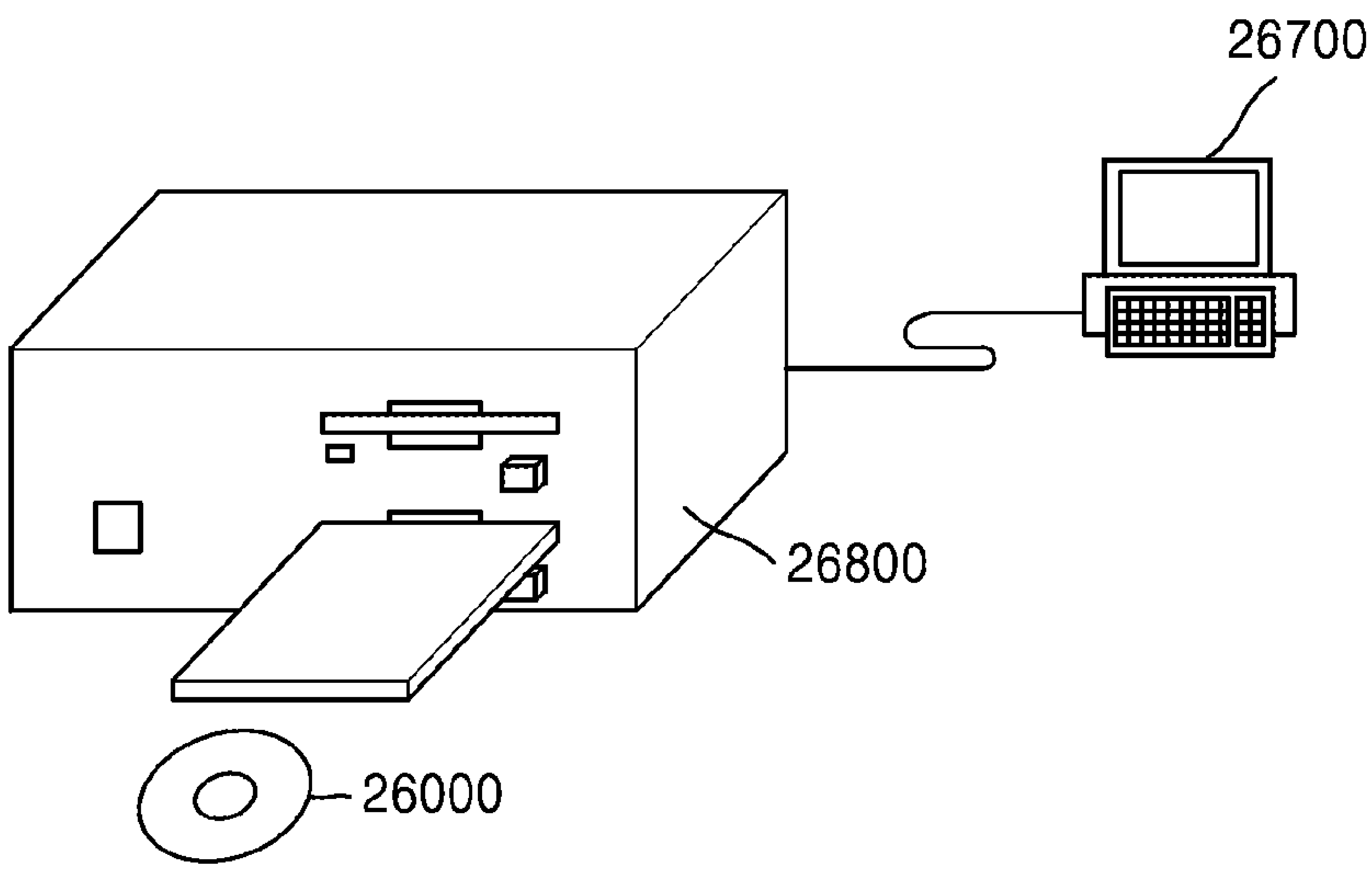


FIG. 44

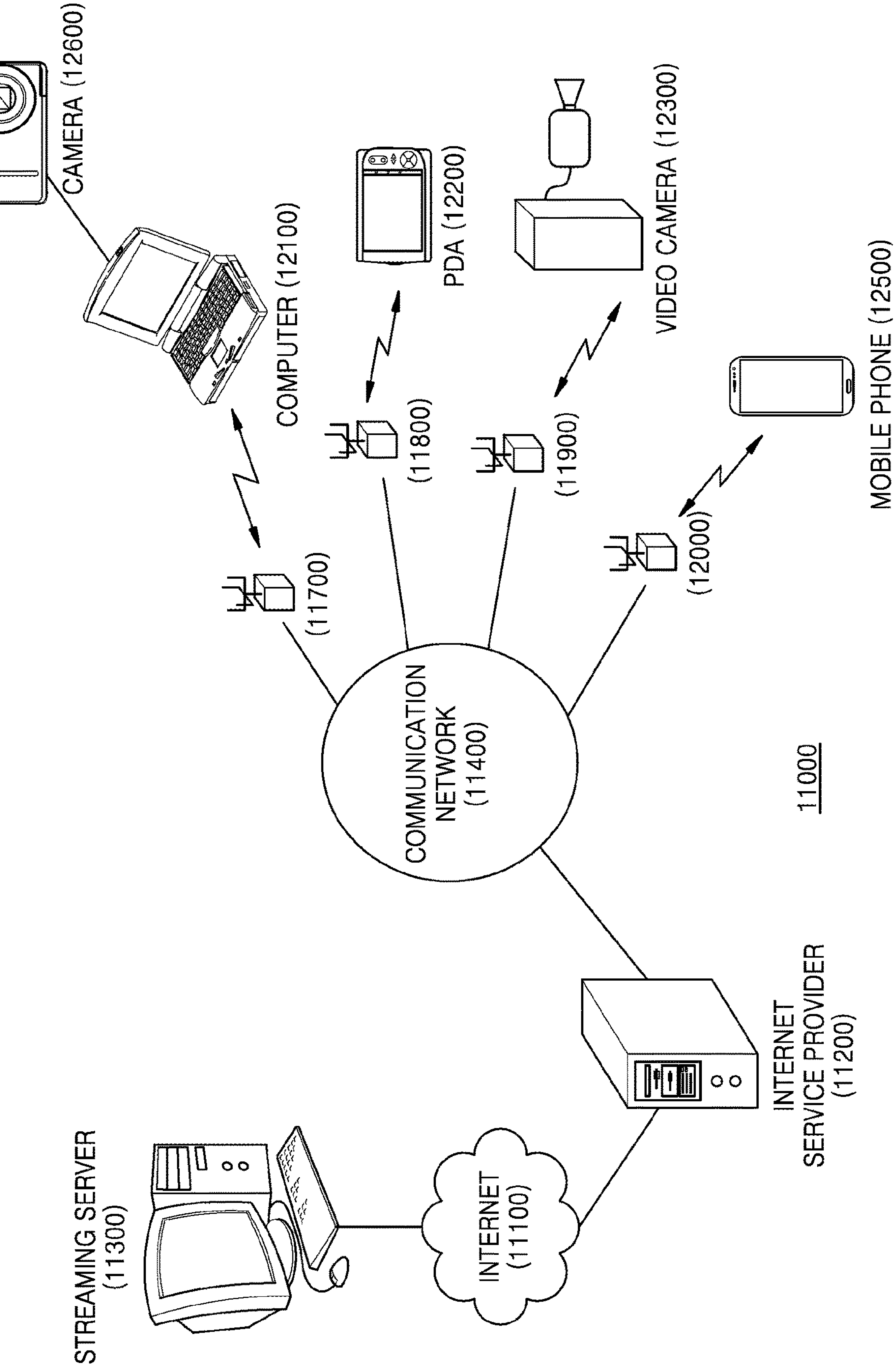

CAMERA (12600)
COMPUTER (12100)
PDA (12200)
VIDEO CAMERA (12300)
MOBILE PHONE (12500)
(11700)
(11800)
(11900)
(12000)
COMMUNICATION NETWORK (11400)
11000
INTERNET SERVICE PROVIDER (11200)
INTERNET (11100)
STREAMING SERVER (11300)

FIG. 45

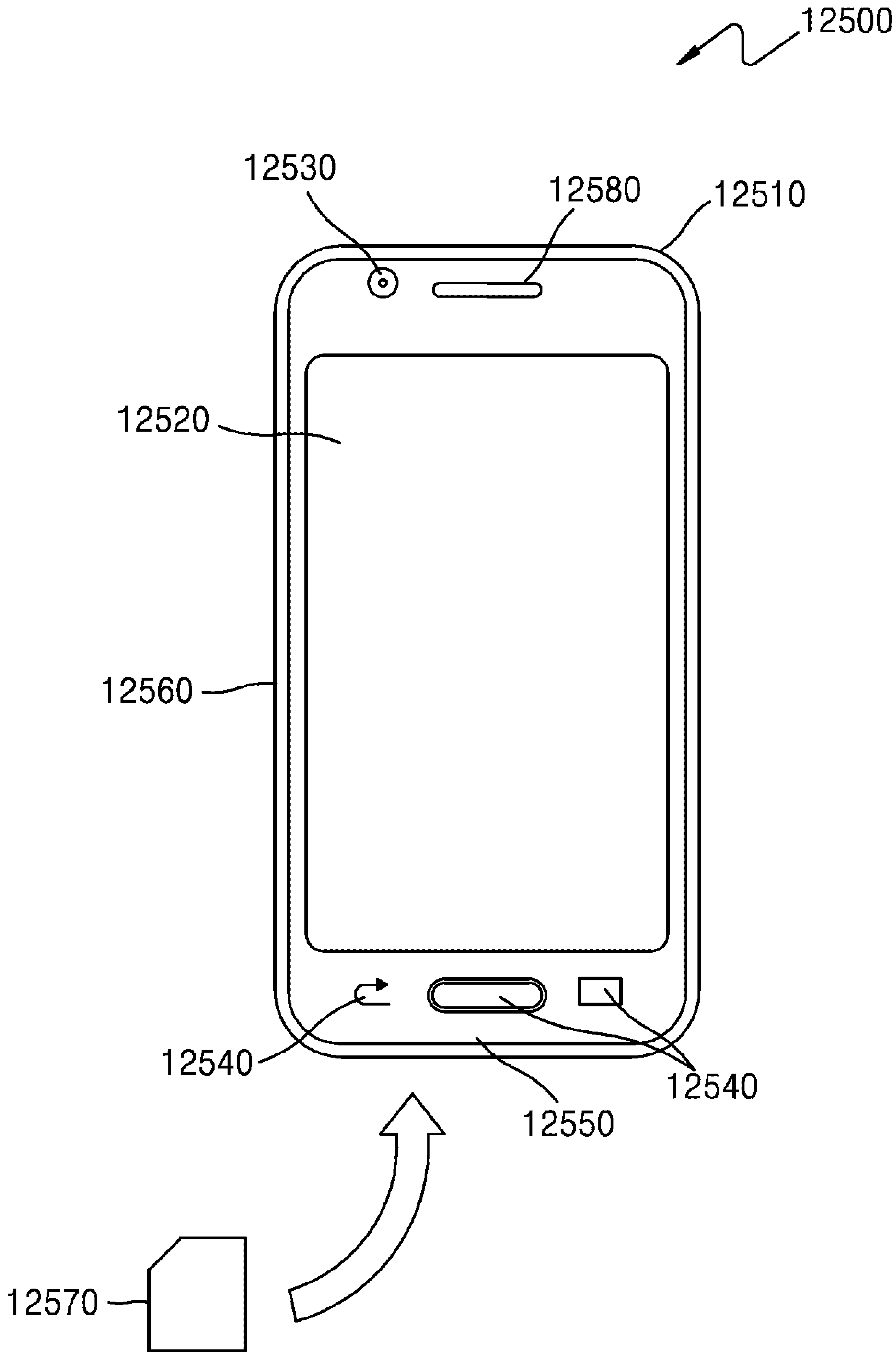

12500
12530
12580
12510
12520
12560
12540
12540
12550
12570

FIG. 46

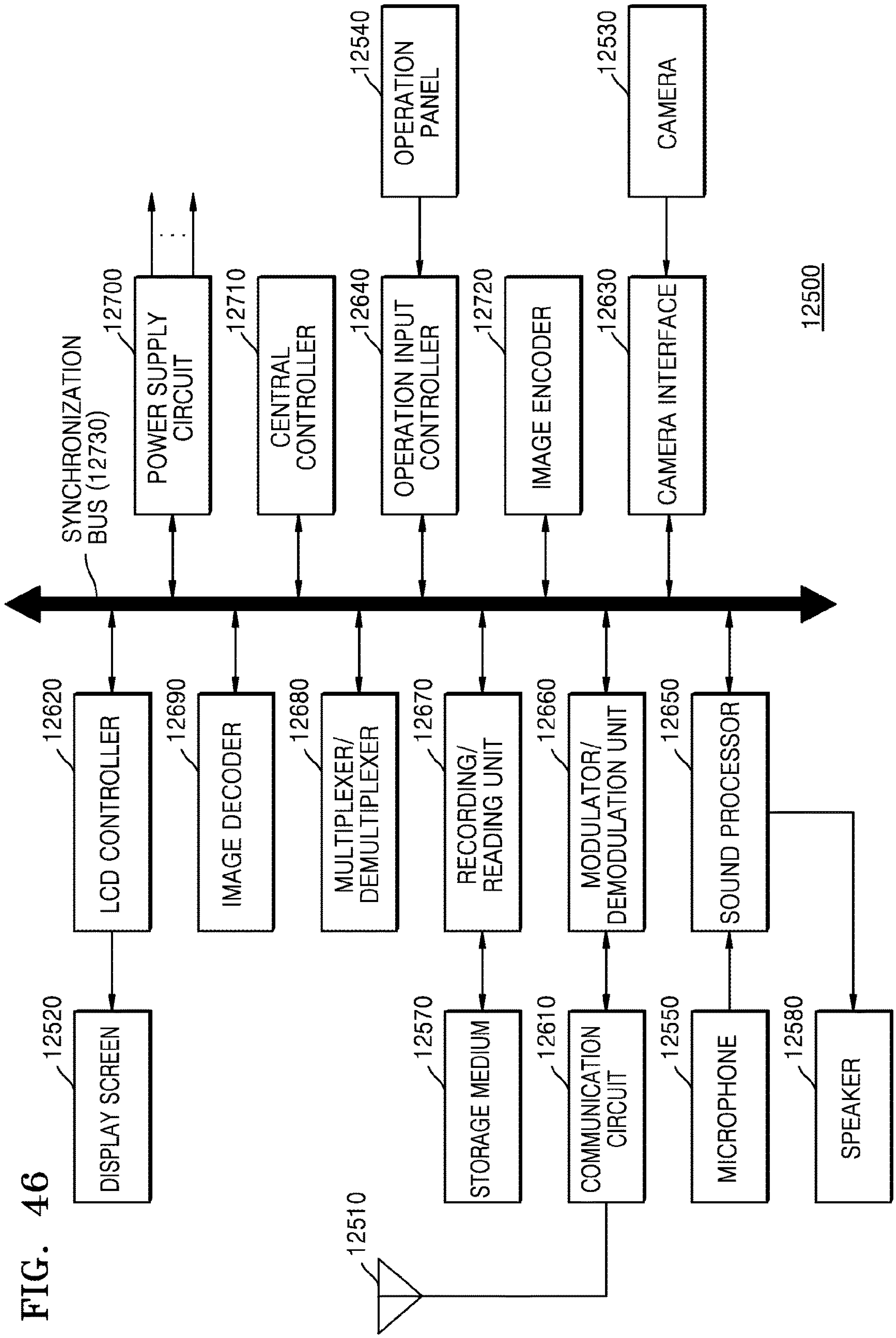

12540
OPERATION PANEL
12530
CAMERA
12700
POWER SUPPLY CIRCUIT
12710
CENTRAL CONTROLLER
12640
OPERATION INPUT CONTROLLER
12720
IMAGE ENCODER
12630
CAMERA INTERFACE
12500
SYNCHRONIZATION BUS (12730)
12620
LCD CONTROLLER
12690
IMAGE DECODER
12680
MULTIPLEXER/ DEMULTIPLEXER
12670
RECORDING/ READING UNIT
12660
MODULATOR/ DEMODULATION UNIT
12650
SOUND PROCESSOR
12520
DISPLAY SCREEN
12570
STORAGE MEDIUM
12610
COMMUNICATION CIRCUIT
12550
MICROPHONE
12580
SPEAKER
12510

FIG. 47

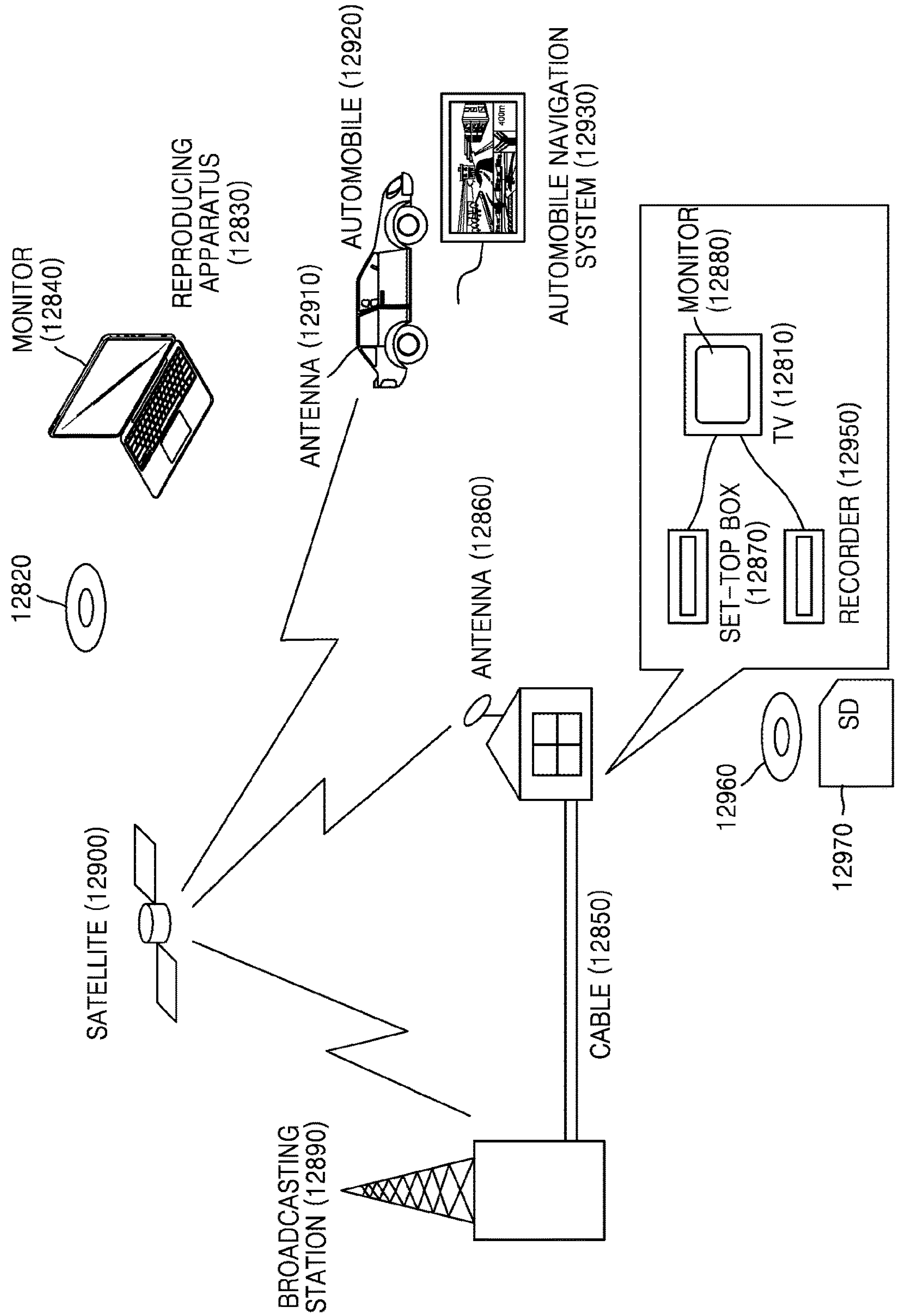
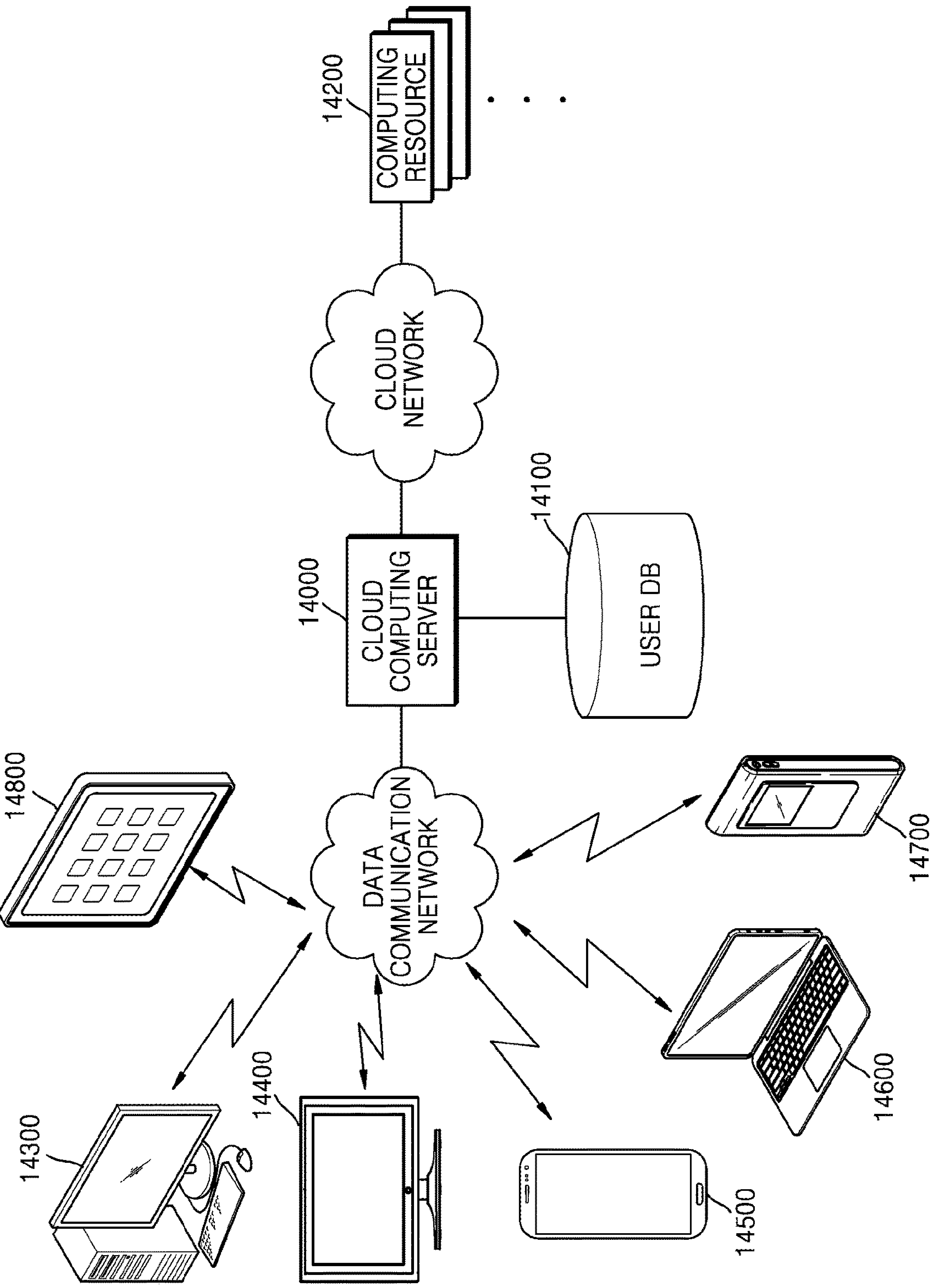

SATELLITE (12900)
12820
MONITOR (12840)
REPRODUCING APPARATUS (12830)
ANTENNA (12910)
AUTOMOBILE (12920)
AUTOMOBILE NAVIGATION SYSTEM (12930)
ANTENNA (12860)
MONITOR (12880)
TV (12810)
SET-TOP BOX (12870)
RECORDER (12950)
12960
SD
12970
CABLE (12850)
BROADCASTING STATION (12890)

FIG. 48


14200
COMPUTING RESOURCE
CLOUD NETWORK
14100
USER DB
14000
CLOUD COMPUTING SERVER
DATA COMMUNICATION NETWORK
14800
14700
14600
14500
14400
14300

PER-SAMPLE PREDICTION ENCODING APPARATUS AND METHOD

TECHNICAL FIELD

The present disclosure relates to video encoding and decoding apparatuses and video encoding and decoding methods using prediction.

BACKGROUND ART

As hardware for reproducing and storing high resolution or high quality video content is being developed and supplied, a need for a video codec for effectively encoding or decoding the high resolution or high quality video content is increasing. Video content is encoded by transforming and quantizing a residual signal obtained by subtracting a prediction signal from an original signal. The encoded video content is decoded to reproduce the video content.

DETAILED DESCRIPTION OF THE INVENTION

Technical Problem

In the process of encoding video content, a residual signal corresponding to a difference between an original signal and a prediction signal is transformed, quantized, and transmitted in a bitstream. Thus, there is a need to minimize the residual signal through efficient prediction.

Technical Solution

A video decoding apparatus includes: a splitter configured to split an image into at least one block; a predictor configured to predict a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and a decoder configured to decode the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

Advantageous Effects of the Invention

Encoding and decoding apparatuses and encoding and decoding methods, according to embodiments, may perform adaptive prediction according to a position of a current sample.

DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a block diagram of a video encoding apparatus based on coding units according to a tree structure, according to an embodiment.

FIG. **2** illustrates a block diagram of a video decoding apparatus based on coding units according to a tree structure, according to an embodiment.

FIG. **3** illustrates a concept of coding units, according to an embodiment.

FIG. **4** illustrates a block diagram of an image encoder based on coding units, according to an embodiment.

FIG. **5** illustrates a block diagram of an image decoder based on coding units, according to an embodiment.

FIG. **6** illustrates deeper coding units according to depths, and partitions, according to an embodiment.

FIG. **7** illustrates a relationship between a coding unit and transformation units, according to an embodiment.

FIG. **8** illustrates a plurality of pieces of encoding information according to depths, according to an embodiment.

FIG. **9** illustrates deeper coding units according to depths, according to an embodiment.

FIGS. **10**, **11**, and **12** illustrate a relationship between coding units, prediction units, and transformation units, according to an embodiment.

FIG. **13** illustrates a relationship between a coding unit and transformation units, according to various embodiments.

FIG. **14** illustrates a multiview video system according to an embodiment.

FIG. **15** illustrates texture images and depth images constituting a multiview video.

FIG. **16** illustrates a block diagram of a video encoding apparatus that can perform sample-wise prediction based on an already predicted adjacent sample.

FIG. **17** illustrates a block diagram of a video decoding apparatus that can perform sample-wise prediction based on an already predicted adjacent sample.

FIG. **18**A illustrates an operation of sample-wise prediction to predict a current sample based on a sample already predicted in a current block.

FIG. **18**B illustrates another operation of sample-wise prediction to predict a current sample based on a sample already predicted in a current block.

FIG. **19** illustrates adjacent samples available for predicting a current sample.

FIG. **20** illustrates weights applied to adjacent samples.

FIG. **21** illustrates a first weight applied to a sample adjacent to a current sample in a horizontal direction.

FIG. **22** illustrates a second weight applied to a sample adjacent to a current sample in a vertical direction.

FIG. **23** illustrates an operation of predicting a sample located at a vertical boundary of a current block.

FIG. **24** illustrates an operation of predicting a sample located at a horizontal boundary of a current block.

FIG. **25** illustrates an operation of predicting a sample located at a corner of a current block.

FIG. **26** illustrates an operation of performing reference sample padding.

FIG. **27** is a flowchart of a video encoding method that can perform sample-wise prediction based on an already predicted adjacent sample.

FIG. **28** is a flowchart of a video decoding method that can perform sample-wise prediction based on an already predicted adjacent sample.

FIG. **29** illustrates a block diagram of a video encoding apparatus that can perform sample-wise prediction based on an already reconstructed sample.

FIG. **30** illustrates a block diagram of a video decoding apparatus that can perform sample-wise prediction based on an already reconstructed sample.

FIG. **31** illustrates an operation of sample-wise prediction to predict a current sample based on an already reconstructed sample.

FIG. **32** illustrates adjacent samples available for predicting a current sample.

FIG. **33** illustrates candidate samples located within a predetermined distance from a current sample.

FIG. **34** illustrates an operation of correcting costs based on a distance between a current sample and a candidate sample.

FIG. **35** illustrates an operation of correcting costs based on a direction in which a candidate adjacent sample is adjacent to a candidate sample.

FIG. **36** illustrates an operation of sample-wise prediction to predict a current sample based on a plurality of already reconstructed samples.

FIG. **37** illustrates an operation of correcting costs based on a direction in which a plurality of candidate adjacent samples are adjacent to a candidate sample.

FIG. **38** illustrates another operation of sample-wise prediction to predict a current sample based on a plurality of already reconstructed samples.

FIG. **39** illustrates an operation of correcting costs based on a direction in which a plurality of candidate adjacent samples are adjacent to a candidate sample.

FIG. **40** is a flowchart of a video encoding method that can perform sample-wise prediction based on an already reconstructed adjacent sample.

FIG. **41** is a flowchart of a video decoding method that can perform sample-wise prediction based on an already reconstructed adjacent sample.

FIG. **42** is a diagram of a physical structure of a disc in which a program is stored, according to an embodiment.

FIG. **43** is a diagram of a disc drive for recording and reading a program by using the disc.

FIG. **44** is a diagram of an overall structure of a content supply system for providing a content distribution service.

FIGS. **45** and **46** illustrate external and internal structures of a mobile phone to which a video encoding method and a video decoding method are applied, according to embodiments.

FIG. **47** illustrates a digital broadcasting system employing a communication system according to an embodiment.

FIG. **48** illustrates a network structure of a cloud computing system using a video encoding apparatus and a video decoding apparatus, according to an embodiment.

BEST MODE

A video decoding apparatus includes: a splitter configured to split an image into at least one block; a predictor configured to predict a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and a decoder configured to decode the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

The first weight may be proportional to a difference value between the first sample adjacent to the current sample in the horizontal direction and a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction.

The second weight may be proportional to a difference value between the second sample adjacent to the current sample in the vertical direction and a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction.

The first weight and the second weight may be equal to each other.

The first sample may be located at a boundary of the current sample, the first sample may be predicted by using at least one of a value obtained by applying a fourth weight to a first reference sample outside the current block and adjacent to the first sample in the horizontal direction and a value obtained by applying a fifth weight to a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction, the fourth weight may be proportional to a difference value between the first reference sample and a second reference sample outside the current block and adjacent to the first sample in a diagonal direction, and the fifth weight may be proportional to a difference value between the third sample and the second reference sample.

The second sample may be located at a boundary of the current sample, the second sample may be predicted by using at least one of a value obtained by applying a fourth weight to a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction and a value obtained by applying a fifth weight to a first reference sample outside the current block and adjacent to the second sample in a vertical direction, the fourth weight may be proportional to a difference value between the third sample and a second reference sample outside the current block and adjacent to the second sample in a diagonal direction, and the fifth weight may be proportional to a difference value between the first reference sample and the second reference sample.

A third sample may be located at a boundary of the current block, the third sample may be obtained by using at least one of a value obtained by applying a fourth weight to a first reference sample outside the current block and adjacent to the third sample in a horizontal direction and a value obtained by applying a fifth weight to a second reference sample outside the current block and adjacent to the third sample in a vertical direction, the fourth weight may be proportional to a difference value between the first reference sample and a third reference sample adjacent to the third sample in a diagonal direction, and the fifth weight may be proportional to a difference value between the second reference sample and the third reference sample.

A video decoding method includes: splitting an image into at least one block; predicting a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and decoding the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

A video encoding apparatus includes: a splitter configured to split an image into at least one block; a predictor configured to predict a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and an encoder configured to encode a residual value between an original value of the current sample and a prediction value of the current sample.

A video encoding method includes: splitting an image into at least one block; predicting a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and encoding a residual value between an original value of the current sample and a prediction value of the current sample.

A video decoding apparatus includes: a splitter configured to split an image into at least one block; a candidate selector configured to select at least one adjacent sample adjacent to a current sample in a current block and select a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block; a predictor configured to predict the current sample by using the first candidate sample; and a decoder configured to decode the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

The candidate samples may be located within a predetermined distance from the current sample.

The first candidate sample may be selected based on a difference value between the adjacent sample adjacent to the current sample and each of candidate adjacent samples adjacent to the candidate samples and a distance between the current sample and each of the candidate samples.

A direction in which the candidate sample is adjacent to the candidate adjacent sample may be identical to a direction in which the current sample is adjacent to the adjacent sample.

The first candidate sample may be selected based on a difference value between the adjacent sample adjacent to the current sample and each of candidate adjacent samples adjacent to the candidate samples, a direction in which the current sample is adjacent to the adjacent sample, and a direction in which the candidate samples are adjacent to the candidate adjacent samples.

A video decoding method includes: splitting an image into at least one block; selecting at least one adjacent sample adjacent to a current sample in a current block and selecting a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block; predicting the current sample by using the first candidate sample; and decoding the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

A video encoding apparatus includes: a splitter configured to split an image into at least one block; a candidate selector configured to select at least adjacent sample predicted earlier than a current sample in a current block and being adjacent to the current sample and select a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block; a predictor configured to predict the current sample by using the first candidate sample; and an encoder configured to encode a residual value between an original value of the current sample and a prediction value of the current sample.

A video encoding method includes: splitting an image into at least one block; selecting at least adjacent sample predicted adjacent to a current sample in a current block and selecting a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block; predicting the current sample by using the first candidate sample; and encoding a residual value between an original value of the current sample and a prediction value of the current sample.

MODE OF THE INVENTION

Hereinafter, an “image” may refer to a still image or a moving image of a video, or a video itself.

Hereinafter, a “sample” refers to data that is assigned to a sampling location of an image and is to be processed. For example, pixels in an image of a spatial domain may be samples.

Hereinafter, a “layer image” denotes specific-view images or specific-type images. One layer image in a multiview video denotes color images or depth images input at a specific view.

Hereinafter, a video encoding scheme and a video decoding scheme based on coding units of a tree structure, according to various embodiments, will be disclosed with reference to FIGS. **1** through **13**.

FIG. **1** illustrates a block diagram of a video encoding apparatus **100** based on coding units of a tree structure, according to an embodiment.

The video encoding apparatus involving video prediction based on coding units of the tree structure **100** includes a coding unit determiner **120** and an output unit **130**. Hereinafter, for convenience of description, the video encoding apparatus **100** involving video prediction based on coding units of the tree structure is referred to as the “video encoding apparatus **100**”.

The coding unit determiner **120** may split a current picture based on a largest coding unit that is a coding unit having a maximum size for a current picture of an image. If the current picture is larger than the largest coding unit, image data of the current picture may be split into the at least one largest coding unit. The largest coding unit according to an embodiment may be a data unit having a size of 32×32, 64×64, 128×128, 256×256, etc., wherein a shape of the data unit is a square having a width and length in squares of 2.

A coding unit according to an embodiment may be characterized by a maximum size and a depth. The depth denotes the number of times the coding unit is spatially split from the largest coding unit, and as the depth deepens, deeper coding units according to depths may be split from the largest coding unit to a smallest coding unit. A depth of the largest coding unit is an uppermost depth and a depth of the smallest coding unit is a lowermost depth. Since a size of a coding unit corresponding to each depth decreases as the depth of the largest coding unit deepens, a coding unit corresponding to an upper depth may include a plurality of coding units corresponding to lower depths.

As described above, the image data of the current picture is split into the largest coding units according to a maximum size of the coding unit, and each of the largest coding units may include deeper coding units that are split according to depths. Since the largest coding unit according to an embodiment is split according to depths, the image data of a spatial domain included in the largest coding unit may be hierarchically classified according to depths.

A maximum depth and a maximum size of a coding unit, which limit the total number of times a height and a width of the largest coding unit are hierarchically split, may be predetermined.

The coding unit determiner **120** encodes at least one split region obtained by splitting a region of the largest coding unit according to depths, and determines a depth to output a finally encoded image data according to the at least one split region. In other words, the coding unit determiner **120** determines a final depth by encoding the image data in the deeper coding units according to depths, according to the largest coding unit of the current picture, and selecting a depth having the minimum encoding error. The determined final depth and image data according to largest coding units are output to the output unit **130**.

The image data in the largest coding unit is encoded based on the deeper coding units corresponding to at least one depth equal to or below the maximum depth, and results of encoding the image data based on each of the deeper coding units are compared. A depth having the minimum encoding error may be selected after comparing encoding errors of the deeper coding units. At least one final depth may be selected for each largest coding unit.

The size of the largest coding unit is split as a coding unit is hierarchically split according to depths, and as the number of coding units increases. Also, even if coding units correspond to the same depth in one largest coding unit, it is determined whether to split each of the coding units corresponding to the same depth to a lower depth by measuring an encoding error of the image data of the each coding unit, separately. Accordingly, even when image data is included in one largest coding unit, the encoding errors may differ according to regions in the one largest coding unit, and thus the final depths may differ according to regions in the image data. Thus, one or more final depths may be determined in one largest coding unit, and the image data of the largest coding unit may be divided according to coding units of at least one final depth.

Accordingly, the coding unit determiner **120** according to the embodiment may determine coding units having a tree structure included in the largest coding unit. The ‘coding units having a tree structure’ according to an embodiment include coding units corresponding to a depth determined to be the final depth, from among all deeper coding units included in the largest coding unit. A coding unit of a final depth may be hierarchically determined according to depths in the same region of the largest coding unit, and may be independently determined in different regions. Equally, a final depth in a current region may be independently determined from a final depth in another region.

A maximum depth according to an embodiment is an index related to the number of splitting times from a largest coding unit to a smallest coding unit. A first maximum depth according to an embodiment may denote the total number of splitting times from the largest coding unit to the smallest coding unit. A second maximum depth according to an embodiment may denote the total number of depth levels from the largest coding unit to the smallest coding unit. For example, when a depth of the largest coding unit is 0, a depth of a coding unit, in which the largest coding unit is split once, may be set to 1, and a depth of a coding unit, in which the largest coding unit is split twice, may be set to 2. Here, if the smallest coding unit is a coding unit in which the largest coding unit is split four times, depth levels of depths 0, 1, 2, 3, and 4 exist, and thus the first maximum depth may be set to 4, and the second maximum depth may be set to 5.

Prediction encoding and transformation may be performed according to the largest coding unit. The prediction encoding and the transformation are also performed based on the deeper coding units according to a depth equal to or depths less than the maximum depth, according to the largest coding unit.

Since the number of deeper coding units increases whenever the largest coding unit is split according to depths, encoding, including the prediction encoding and the transformation, is performed on all of the deeper coding units generated as the depth deepens. Hereinafter, for convenience of description, the prediction encoding and the transformation will be described based on a coding unit of a current depth in at least one largest coding unit.

The video encoding apparatus **100** according to the embodiment may variously select a size or shape of a data unit for encoding the image data. In order to encode the image data, operations, such as prediction encoding, transformation, and entropy encoding, are performed, and at this time, the same data unit may be used for all operations or different data units may be used for each operation.

For example, the video encoding apparatus **100** may select not only a coding unit for encoding the image data, but may also select a data unit different from the coding unit so as to perform the prediction encoding on the image data in the coding unit.

In order to perform prediction encoding in the largest coding unit, the prediction encoding may be performed based on a coding unit of a final depth, i.e., based on the coding unit that is no longer split. A partition obtained by splitting a coding unit may include a coding unit and a data unit obtained by splitting at least one of a height and a width of the coding unit. A partition may include a data unit where a coding unit is split, and a data unit having the same size as the coding unit. A partition that is a base of prediction may be referred to as a ‘prediction unit’.

For example, when a coding unit of 2N×2N (where N is a positive integer) is no longer split and becomes a prediction unit of 2N×2N, and a size of a partition may be 2N×2N, 2N×N, N×2N, or N×N. Examples of a partition mode according to an embodiment include symmetrical partitions that are obtained by symmetrically splitting a height or width of the prediction unit, partitions obtained by asymmetrically splitting the height or width of the prediction unit, such as 1:n or n:1, partitions that are obtained by geometrically splitting the prediction unit, and partitions having arbitrary shapes.

A prediction mode of the prediction unit may be at least one of an intra mode, an inter mode, and a skip mode. For example, the intra mode and the inter mode may be performed on the partition of 2N×2N, 2N×N, N×2N, or N×N. Also, the skip mode may be performed only on the partition of 2N×2N. The encoding may be independently performed on one prediction unit in a coding unit, so that a prediction mode having a minimum encoding error may be selected.

The video encoding apparatus **100** according to the embodiment may also perform the transformation on the image data in a coding unit based on not only the coding unit for encoding the image data, but also based on a data unit that is different from the coding unit. In order to perform the transformation in the coding unit, the transformation may be performed based on a transformation unit having a size smaller than or equal to the coding unit. For example, the transformation unit may include a data unit for an intra mode and a transformation unit for an inter mode.

The transformation unit in the coding unit may be recursively split into smaller sized regions in a manner similar to that in which the coding unit is split according to the tree structure, according to an embodiment. Thus, residual data in the coding unit may be split according to the transformation unit having the tree structure according to transformation depths.

A transformation depth indicating the number of splitting times to reach the transformation unit by splitting the height and width of the coding unit may also be set in the transformation unit according to an embodiment. For example, in a current coding unit of 2N×2N, a transformation depth may be 0 when the size of a transformation unit is 2N×2N, may be 1 when the size of the transformation unit is N×N, and may be 2 when the size of the transformation unit is N/2×N/2. In other words, the transformation unit having the tree structure may be set according to the transformation depths.

Split information according to depths requires not only information about a depth but also requires information related to prediction and transformation.

Accordingly, the coding unit determiner **120** may determine not only a depth generating a minimum encoding error but may also determine a partition mode in which a prediction unit is split to partitions, a prediction mode according to prediction units, and a size of a transformation unit for transformation.

A method of determining the coding unit, the prediction unit, the partition, and the transformation unit according to the tree structure of the largest coding unit, according to an embodiment, will be described below in detail with reference to FIGS. **3** through **13**.

The coding unit determiner **120** may measure an encoding error of deeper coding units according to depths by using Rate-Distortion Optimization based on Lagrangian multipliers.

The output unit **130** outputs the image data of the largest coding unit, which is encoded based on the at least one depth determined by the coding unit determiner **120**, and split information according to the depth, in bitstreams.

The encoded image data may be obtained by encoding residual data of an image.

The split information according to depth may include information about the depth, about the partition mode in the prediction unit, about the prediction mode, and about split of the transformation unit.

Final-depth information may be defined by using split information according to depths, which indicates whether encoding is performed on coding units of a lower depth instead of a current depth. If the current depth of the current coding unit is a depth, the current coding unit is encoded by using the coding unit of the current depth, and thus split information of the current depth may be defined not to split the current coding unit to a lower depth. On the contrary, if the current depth of the current coding unit is not the depth, the encoding has to be performed on the coding unit of the lower depth, and thus the split information of the current depth may be defined to split the current coding unit to the coding units of the lower depth.

If the current depth is not the depth, encoding is performed on the coding unit that is split into the coding unit of the lower depth. Since at least one coding unit of the lower depth exists in one coding unit of the current depth, the encoding is repeatedly performed on each coding unit of the lower depth, and thus the encoding may be recursively performed for the coding units having the same depth.

Since the coding units having a tree structure are determined for one largest coding unit, and at least one piece of split information has to be determined for a coding unit of a depth, at least one piece of split information may be determined for one largest coding unit. Also, data of the largest coding unit may vary according to locations since the data is hierarchically split according to depths, and thus a depth and split information may be set for the data.

Accordingly, the output unit **130** according to the embodiment may assign encoding information about a corresponding depth and an encoding mode to at least one of the coding unit, the prediction unit, and a minimum unit included in the largest coding unit.

The minimum unit according to an embodiment is a square data unit obtained by splitting the smallest coding unit constituting the lowermost depth by 4. Alternatively, the minimum unit according to an embodiment may be a maximum square data unit that may be included in all of the coding units, prediction units, partition units, and transformation units included in the largest coding unit.

For example, the encoding information output by the output unit **130** may be classified into encoding information according to deeper coding units, and encoding information according to prediction units. The encoding information according to the deeper coding units may include the prediction mode information and the partition size information. The encoding information according to the prediction units may include information about an estimated direction during an inter mode, about a reference image index of the inter mode, about a motion vector, about a chroma component of an intra mode, and about an interpolation method during the intra mode.

Information about a maximum size of the coding unit defined according to pictures, slices, or GOPs, and information about a maximum depth may be inserted into a header of a bitstream, a sequence parameter set, or a picture parameter set.

Information about a maximum size of the transformation unit permitted with respect to a current video, and information about a minimum size of the transformation unit may also be output through a header of a bitstream, a sequence parameter set, or a picture parameter set. The output unit **130** may encode and output reference information, prediction information, and slice type information, which are related to prediction.

In the video encoding apparatus **100** according to the simplest embodiment, the deeper coding unit may be a coding unit obtained by dividing a height and width of a coding unit of an upper depth, which is one layer above, by two. That is, when the size of the coding unit of the current depth is 2N×2N, the size of the coding unit of the lower depth is N×N. Also, a current coding unit having a size of 2N×2N may maximally include four lower-depth coding units having a size of N×N.

Accordingly, the video encoding apparatus **100** may form the coding units having the tree structure by determining coding units having an optimum shape and an optimum size for each largest coding unit, based on the size of the largest coding unit and the maximum depth determined considering characteristics of the current picture. Also, since encoding may be performed on each largest coding unit by using any one of various prediction modes and transformations, an optimum encoding mode may be determined by taking into account characteristics of the coding unit of various image sizes.

Thus, if an image having a high resolution or a large data amount is encoded in a conventional macroblock, the number of macroblocks per picture excessively increases. Accordingly, the number of pieces of compressed information generated for each macroblock increases, and thus it is difficult to transmit the compressed information and data compression efficiency decreases. However, by using the video encoding apparatus according to the embodiment, image compression efficiency may be increased since a coding unit is adjusted while considering characteristics of an image while increasing a maximum size of a coding unit while considering a size of the image.

FIG. **2** is a block diagram of a video decoding apparatus **200** based on coding units according to tree structure, according to various embodiments.

The video decoding apparatus **200** involving video prediction based on coding units of the tree structure according to the embodiment includes a receiver **210**, an image data and encoding information extractor **220**, and an image data decoder **230**. Hereinafter, for convenience of description, the video decoding apparatus **200** involving video prediction based on coding units of the tree structure according to the embodiment is referred to as the "video decoding apparatus **200**".

Definitions of various terms, such as a coding unit, a depth, a prediction unit, a transformation unit, and various types of split information for decoding operations of the video decoding apparatus **200** according to the embodiment are identical to those described with reference to FIG. **1** and the video encoding apparatus **100**.

The receiver **210** receives and parses a bitstream of an encoded video. The image data and encoding information extractor **220** extracts encoded image data for each coding unit from the parsed bitstream, wherein the coding units have a tree structure according to each largest coding unit, and outputs the extracted image data to the image data decoder **230**. The image data and encoding information extractor **220** may extract information about a maximum size of a coding unit of a current picture, from a header about the current picture, a sequence parameter set, or a picture parameter set.

Also, the image data and encoding information extractor **220** extracts a final depth and split information for the coding units having a tree structure according to each largest coding unit, from the parsed bitstream. The extracted final depth and split information are output to the image data decoder **230**. That is, the image data in a bitstream is split into the largest coding unit so that the image data decoder **230** may decode the image data for each largest coding unit.

A depth and split information according to each of the largest coding units may be set for one or more pieces of depth information, and split information according to depths may include partition mode information of a corresponding coding unit, prediction mode information, and split information of a transformation unit. Also, as the depth information, the split information according to depths may be extracted.

The depth and the split information according to each of the largest coding units extracted by the image data and encoding information extractor **220** are a depth and split information determined to generate a minimum encoding error when an encoder, such as the video encoding apparatus **100**, repeatedly performs encoding for each deeper coding unit according to depths according to each largest coding unit. Accordingly, the video decoding apparatus **200** may reconstruct an image by decoding data according to an encoding method that generates the minimum encoding error.

Since encoding information about the depth and the encoding mode may be assigned to a predetermined data unit from among a corresponding coding unit, a prediction unit, and a minimum unit, the image data and encoding information extractor **220** may extract the depth and the split information according to the predetermined data units. If a depth and split information of a corresponding largest coding unit are recorded according to each of the predetermined data units, predetermined data units having the same depth and the split information may be inferred to be the data units included in the same largest coding unit.

The image data decoder **230** may reconstruct the current picture by decoding the image data in each largest coding unit based on the depth and the split information according to the largest coding units. That is, the image data decoder **230** may decode the encoded image data, based on a read partition mode, a prediction mode, and a transformation unit for each coding unit from among the coding units having the tree structure included in each largest coding unit. A decoding process may include a prediction process including intra prediction and motion compensation, and an inverse transformation process.

The image data decoder **230** may perform intra prediction or motion compensation according to a partition and a prediction mode of each coding unit, based on the information about the partition mode and the prediction mode of the prediction unit of the coding unit according to depths.

In addition, the image data decoder **230** may read information about a transformation unit according to a tree structure for each coding unit so as to perform inverse transformation based on transformation units for each coding unit, for inverse transformation for each largest coding unit. Via the inverse transformation, a pixel value of a spatial region of the coding unit may be reconstructed.

The image data decoder **230** may determine a depth of a current largest coding unit by using split information according to depths. If the split information indicates that image data is no longer split in the current depth, the current depth is a depth. Accordingly, the image data decoder **230** may decode the image data of the current largest coding unit by using the information about the partition mode of the prediction unit, the prediction mode, and the size of the transformation unit for each coding unit corresponding to the current depth.

That is, data units containing the encoding information including the same split information may be gathered by observing the encoding information set assigned for the predetermined data unit from among the coding unit, the prediction unit, and the minimum unit, and the gathered data units may be considered to be one data unit to be decoded by the image data decoder **230** in the same encoding mode. As such, the current coding unit may be decoded by obtaining the information about the encoding mode for each coding unit.

The image decoding apparatus **30** described above with reference to FIG. **3**A may include the video decoding apparatuses **200** corresponding to the number of views, so as to reconstruct first layer images and second layer images by decoding a received first layer image stream and a received second layer image stream.

When the first layer image stream is received, the image data decoder **230** of the video decoding apparatus **200** may split samples of the first layer images, which are extracted from the first layer image stream by an extractor **220**, into coding units according to a tree structure of a largest coding unit. The image data decoder **230** may perform motion compensation, based on prediction units for the inter-image prediction, on each of the coding units according to the tree structure of the samples of the first layer images, and may reconstruct the first layer images.

When the second layer image stream is received, the image data decoder **230** of the video decoding apparatus **200** may split samples of the second layer images, which are extracted from the second layer image stream by the extractor **220**, into coding units according to a tree structure of a largest coding unit. The image data decoder **230** may perform motion compensation, based on prediction units for the inter-image prediction, on each of the coding units of the samples of the second layer images, and may reconstruct the second layer images.

The extractor **220** may obtain, from a bitstream, information related to a luminance error so as to compensate for a luminance difference between the first layer image and the second layer image. However, whether to perform luminance compensation may be determined according to an encoding mode of a coding unit. For example, the luminance compensation may be performed only on a prediction unit having a size of 2N×2N.

Thus, the video decoding apparatus **200** may obtain information about at least one coding unit that generates the minimum encoding error when encoding is recursively performed for each largest coding unit, and may use the information to decode the current picture. That is, the coding units having the tree structure determined to be the optimum coding units in each largest coding unit may be decoded.

Accordingly, even if an image has high resolution or has an excessively large data amount, the image may be efficiently decoded and reconstructed by using a size of a coding unit and an encoding mode, which are adaptively determined according to characteristics of the image, by using optimal split information received from an encoding terminal.

FIG. **3** illustrates a concept of coding units according to various embodiments.

A size of a coding unit may be expressed by width×height, and may be 64×64, 32×32, 16×16, and 8×8. A coding unit of 64×64 may be split into partitions of 64×64, 64×32, 32×64, or 32×32, and a coding unit of 32×32 may be split into partitions of 32×32, 32×16, 16×32, or 16×16, a coding unit of 16×16 may be split into partitions of 16×16, 16×8, 8×16, or 8×8, and a coding unit of 8×8 may be split into partitions of 8×8, 8×4, 4×8, or 4×4.

In video data **310**, a resolution is 1920×1080, a maximum size of a coding unit is 64, and a maximum depth is 2. In video data **320**, a resolution is 1920×1080, a maximum size of a coding unit is 64, and a maximum depth is 3. In video data **330**, a resolution is 352×288, a maximum size of a coding unit is 16, and a maximum depth is 1. The maximum depth shown in FIG. **3** denotes a total number of splits from a largest coding unit to a smallest coding unit.

If a resolution is high or a data amount is large, a maximum size of a coding unit may be large so as to not only increase encoding efficiency but also to accurately reflect characteristics of an image. Accordingly, the maximum size of the coding unit of the video data **310** and **320** having a higher resolution than the video data **330** may be selected to 64.

Since the maximum depth of the video data **310** is 2, coding units **315** of the video data **310** may include a largest coding unit having a long axis size of 64, and coding units having long axis sizes of 32 and 16 since depths are deepened to two layers by splitting the largest coding unit twice. Since the maximum depth of the video data **330** is 1, coding units **335** of the video data **330** may include a largest coding unit having a long axis size of 16, and coding units having a long axis size of 8 since depths are deepened to one layer by splitting the largest coding unit once.

Since the maximum depth of the video data **320** is 3, coding units **325** of the video data **320** may include a largest coding unit having a long axis size of 64, and coding units having long axis sizes of 32, 16, and 8 since the depths are deepened to 3 layers by splitting the largest coding unit three times. As a depth deepens, an expression capability with respect to detailed information may be improved.

FIG. **4** is a block diagram of an image encoder **400** based on coding units, according to various embodiments.

The image encoder **400** according to an embodiment performs operations of the coding unit determiner **120** of the video encoding apparatus **100** so as to encode image data. In other words, an intra predictor **420** performs intra prediction on coding units in an intra mode, from among a current image **405**, per prediction unit, and an inter predictor **415** performs inter prediction on coding units in an inter mode by using the current image **405** and a reference image obtained by a reconstructed picture buffer **410**, per prediction unit. The current picture **405** may be split into largest coding units, and then the largest coding units may be sequentially encoded. In this regard, the largest coding unit that is to be split into coding units having a tree structure may be encoded.

Residual data is generated by subtracting prediction data of a coding unit of each mode output from the intra predictor **420** or the inter predictor **415** from data of the current image **405** to be encoded, and the residual data is output as a quantized transformation coefficient through a transformer **425** and a quantizer **430** per transformation unit. The quantized transformation coefficient is reconstructed to residual data in a spatial domain through an inverse-quantizer **445** and an inverse-transformer **450**. The reconstructed residue data in the spatial domain is added to the prediction data of the coding unit of each mode output from the intra predictor **420** or the inter predictor **415** to be reconstructed as data in a spatial domain of the coding unit of the current image **405**. The data in the spatial domain passes through a deblocker **455** and a sample adaptive offset (SAO) performer **460** and thus a reconstructed image is generated. The reconstructed image is stored in the reconstructed picture buffer **410**. Reconstructed images stored in the reconstructed picture buffer **410** may be used as a reference image for inter prediction of another image. The quantized transformation coefficient obtained through the transformer **425** and the quantizer **430** may be output as a bitstream **440** through an entropy encoder **435**.

In order for the image encoder **400** to be applied in the video encoding apparatus **100**, all elements of the image encoder **400**, i.e., the inter predictor **415**, the intra predictor **420**, the transformer **425**, the quantizer **430**, the entropy encoder **435**, the inverse-quantizer **445**, the inverse-transformer **450**, the deblocker **455**, and the SAO performer **460**, may perform operations based on each coding unit among coding units having a tree structure according to each largest coding unit.

In particular, the intra predictor **420** and the inter predictor **415** may determine partitions and a prediction mode of each coding unit from among the coding units having a tree structure while considering the maximum size and the maximum depth of a current largest coding unit, and the transformer **425** may determine whether to split a transformation unit according to a quad-tree in each coding unit from among the coding units having the tree structure.

FIG. **5** is a block diagram of an image decoder **500** based on coding units according to various embodiments.

An entropy decoder **515** parses encoded image data that is to be decoded and encoding information required for decoding from a bitstream **505**. The encoded image data is a quantized transformation coefficient, and an inverse-quantizer **520** and an inverse-transformer **525** reconstructs residual data from the quantized transformation coefficient.

An intra predictor **540** performs intra prediction on a coding unit in an intra mode according to prediction units. An inter predictor **535** performs inter prediction on a coding unit in an inter mode from a current image according to prediction units, by using a reference image obtained by a reconstructed picture buffer **530**.

Prediction data and residue data regarding coding units of each mode, which passed through the intra predictor **540** and the inter predictor **535**, are summed, so that data in a spatial domain regarding coding units of the current image **405** may be reconstructed, and the reconstructed data in the spatial domain may be output as a reconstructed image **560** through a deblocker **545** and an SAO performer **550**. Also, reconstructed images that are stored in the reconstructed picture buffer **530** may be output as reference images.

In order for a image data decoder **230** of the video decoding apparatus **200** to decode the image data, operations after the entropy decoder **515** of the image decoder **500** according to an embodiment may be performed.

In order for the image decoder **500** to be applied in the video decoding apparatus **200** according to an embodiment, all elements of the image decoder **500**, i.e., the entropy decoder **515**, the inverse-quantizer **520**, the inverse-transformer **525**, the intra predictor **540**, the inter predictor **535**, the deblocker **545**, and the SAO performer **550** may perform operations based on coding units having a tree structure for each largest coding unit.

In particular, the intra predictor **540** and the inter predictor **535** determine a partition mode and a prediction mode according to each of coding units having a tree structure, and the inverse-transformer **525** may determine whether to split a transformation unit according to a quad-tree structure per coding unit.

FIG. **6** illustrates coding units according to depths and partitions, according to various embodiments.

The video encoding apparatus **100** according to an embodiment and the video decoding apparatus **200** according to an embodiment use hierarchical coding units so as to consider characteristics of an image. A maximum height, a maximum width, and a maximum depth of coding units may be adaptively determined according to the characteristics of the image, or may be variously set according to user requirements. Sizes of deeper coding units according to depths may be determined according to the predetermined maximum size of the coding unit.

In a hierarchical structure of coding units **600** according to an embodiment, the maximum height and the maximum width of the coding units are each 64, and the maximum depth is 3. In this case, the maximum depth refers to a total number of times the coding unit is split from the largest coding unit to the smallest coding unit. Since a depth deepens along a vertical axis of the hierarchical structure of coding units **600**, a height and a width of the deeper coding unit are each split. Also, a prediction unit and partitions, which are bases for prediction encoding of each deeper coding unit, are shown along a horizontal axis of the hierarchical structure **600**.

That is, a coding unit **610** is a largest coding unit in the hierarchical structure **600**, wherein a depth is 0 and a size, i.e., a height by width, is 64×64. The depth deepens along the vertical axis, and a coding unit **620** having a size of 32×32 and a depth of 1, a coding unit **630** having a size of 16×16 and a depth of 2, and a coding unit **640** having a size of 8×8 and a depth of 3 are present. The coding unit **640** having a size of 8×8 and a depth of 3 is a smallest coding unit.

The prediction unit and the partitions of a coding unit are arranged along the horizontal axis according to each depth. In other words, if the coding unit **610** having a size of 64×64 and a depth of 0 is a prediction unit, the prediction unit may be split into partitions included in the coding unit **610** having a size of 64×64, i.e. a partition **610** having a size of 64×64, partitions **612** having the size of 64×32, partitions **614** having the size of 32×64, or partitions **616** having the size of 32×32.

Equally, a prediction unit of the coding unit **620** having the size of 32×32 and the depth of 1 may be split into partitions included in the coding unit **620** having a size of 32×32, i.e. a partition **620** having a size of 32×32, partitions **622** having a size of 32×16, partitions **624** having a size of 16×32, and partitions **626** having a size of 16×16.

Equally, a prediction unit of the coding unit **630** having the size of 16×16 and the depth of 2 may be split into partitions included in the coding unit **630** having a size of 16×16, i.e. a partition having a size of 16×16 included in the coding unit **630**, partitions **632** having a size of 16×8, partitions **634** having a size of 8×16, and partitions **636** having a size of 8×8.

Equally, a prediction unit of the coding unit **640** having the size of 8×8 and the depth of 3 may be split into partitions included in the coding unit **640** having a size of 8×8, i.e. a partition **640** having a size of 8×8 included in the coding unit **640**, partitions **642** having a size of 8×4, partitions **644** having a size of 4×8, and partitions **646** having a size of 4×4.

In order to determine a depth of the largest coding unit **610**, the coding unit determiner **120** of the video encoding apparatus **100** has to perform encoding on coding units respectively corresponding to depths included in the largest coding unit **610**.

The number of deeper coding units according to depths including data in the same range and the same size increases as the depth deepens. For example, four coding units corresponding to a depth of 2 are required to cover data that is included in one coding unit corresponding to a depth of 1. Accordingly, in order to compare encoding results of the same data according to depths, the coding unit corresponding to the depth of 1 and four coding units corresponding to the depth of 2 are each encoded.

In order to perform encoding according to each of the depths, a minimum encoding error that is a representative encoding error of a corresponding depth may be selected by performing encoding on each of prediction units of the coding units according to depths, along the horizontal axis of the hierarchical structure of coding units **600**. Alternatively, the minimum encoding error may be searched for by comparing the minimum encoding errors according to depths, by performing encoding for each depth as the depth deepens along the vertical axis of the hierarchical structure **600**. A depth and a partition having the minimum encoding error in the largest coding unit **610** may be selected as the depth and a partition mode of the largest coding unit **610**.

FIG. **7** illustrates a relationship between a coding unit and transformation units, according to various embodiments.

The video encoding apparatus **100** according to an embodiment or the video decoding apparatus **200** according to an embodiment encodes or decodes an image according to coding units having sizes smaller than or equal to a largest coding unit for each largest coding unit. Sizes of transformation units for transformation during encoding may be selected based on data units that are not larger than a corresponding coding unit.

For example, in the video encoding apparatus **100** or the video decoding apparatus **200**, when a size of the coding unit **710** is 64×64, transformation may be performed by using the transformation units **720** having a size of 32×32.

Also, data of the coding unit **710** having the size of 64×64 may be encoded by performing the transformation on each of the transformation units having the size of 32×32, 16×16, 8×8, and 4×4, which are smaller than 64×64, and then a transformation unit having the minimum coding error may be selected.

FIG. **8** illustrates a plurality of pieces of encoding information according to depths, according to various embodiments.

The output unit **130** of the video encoding apparatus **100** according to an embodiment may encode and transmit, as split information, partition mode information **800**, prediction mode information **810**, and transformation unit size information **820** for each coding unit corresponding to a depth.

The partition mode information **800** indicates information about a shape of a partition obtained by splitting a prediction unit of a current coding unit, wherein the partition is a data unit for prediction encoding the current coding unit. For example, a current coding unit CU_**0** having a size of 2N×2N may be split into any one of a partition **802** having a size of 2N×2N, a partition **804** having a size of 2N×N, a partition **806** having a size of N×2N, and a partition **808** having a size of N×N. In this case, the partition mode information **800** about a current coding unit is set to indicate one of the partition **802** having a size of 2N×2N, the partition **804** having a size of 2N×N, the partition **806** having a size of N×2N, and the partition **808** having a size of N×N.

The prediction mode information **810** indicates a prediction mode of each partition. For example, the prediction mode information **810** may indicate a mode of prediction encoding performed on a partition indicated by the partition mode information **800**, i.e., an intra mode **812**, an inter mode **814**, or a skip mode **816**.

The transformation unit size information **820** represents a transformation unit to be based on when transformation is performed on a current coding unit. For example, the transformation unit may be a first intra transformation unit **822**, a second intra transformation unit **824**, a first inter transformation unit **826**, or a second inter transformation unit **828**.

The image data and encoding information extractor **220** of the video decoding apparatus **200** may extract and use the partition mode information **800**, the prediction mode information **810**, and the transformation unit size information **820** for each deeper coding unit.

FIG. **9** is a diagram of coding units according to depths, according to various embodiments.

Split information may be used to indicate a change in a depth. The spilt information indicates whether a coding unit of a current depth is split into coding units of a lower depth.

A prediction unit **910** for prediction encoding a coding unit **900** having a depth of 0 and a size of 2N_0×2N_0 may include partitions of a partition mode **912** having a size of 2N_0×2N_0, a partition mode **914** having a size of 2N_0×N_0, a partition mode **916** having a size of N_0×2N_0, and a partition mode **918** having a size of N_0×N_0. Only the partition modes **912**, **914**, **916**, and **918** which are obtained by symmetrically splitting the prediction unit are illustrated, but as described above, a partition mode is not limited thereto and may include asymmetrical partitions, partitions having a predetermined shape, and partitions having a geometrical shape.

According to each partition mode, prediction encoding has to be repeatedly performed on one partition having a size of 2N_0×2N_0, two partitions having a size of 2N_0×N_0, two partitions having a size of N_0×2N_0, and four partitions having a size of N_0×N_0. The prediction encoding in an intra mode and an inter mode may be performed on the partitions having the sizes of 2N_0×2N_0, N_0×2N_0, 2N_0×N_0, and N_0×N_0. The prediction encoding in a skip mode may be performed only on the partition having the size of 2N_0×2N_0.

If an encoding error is smallest in one of the partition modes **912**, **914**, and **916** having the sizes of 2N_0×2N_0, 2N_0×N_0 and N_0×2N_0, the prediction unit **910** may not be split into a lower depth.

If the encoding error is the smallest in the partition mode **918** having the size of N_0×N_0, a depth is changed from 0 to 1 and split is performed (operation **920**), and encoding may be repeatedly performed on coding units **930** of a partition mode having a depth of 2 and a size of N_0×N_0 so as to search for a minimum encoding error.

A prediction unit **940** for prediction encoding the coding unit **930** having a depth of 1 and a size of 2N_1×2N_1 (=N_0×N_0) may include partitions of a partition mode **942** having a size of 2N_1×2N_1, a partition mode **944** having a size of 2N_1×N_1, a partition mode **946** having a size of N_1×2N_1, and a partition mode **948** having a size of N_1×N_1.

If an encoding error is the smallest in the partition mode **948** having the size of N_1×N_1, a depth is changed from 1 to 2 and split is performed (in operation **950**), and encoding is repeatedly performed on coding units **960** having a depth of 2 and a size of N_2×N_2 so as to search for a minimum encoding error.

When a maximum depth is d, deeper coding units according to depths may be set until when a depth corresponds to d−1, and split information may be set until when a depth corresponds to d−2. In other words, when encoding is performed up to when the depth is d−1 after a coding unit corresponding to a depth of d−2 is split in operation **970**, a prediction unit **990** for prediction encoding a coding unit **980** having a depth of d−1 and a size of 2N_(d−1)×2N_(d−1) may include partitions of a partition mode **992** having a size of 2N_(d−1)×2N_(d−1), a partition mode **994** having a size of 2N_(d−1)×N_(d−1), a partition mode **996** having a size of N_(d−1)×2N_(d−1), and a partition mode **998** having a size of N_(d−1)×N_(d−1).

Prediction encoding may be repeatedly performed on one partition having a size of 2N_(d−1)×2N_(d−1), two partitions having a size of 2N_(d−1)×N_(d−1), two partitions having a size of N_(d−1)×2N_(d−1), four partitions having a size of N_(d−1)×N_(d−1) from among the partition modes so as to search for a partition mode having a minimum encoding error.

Even when the partition mode **998** having the size of N_(d−1)×N_(d−1) has the minimum encoding error, since a maximum depth is d, a coding unit CU_(d−1) having a depth of d−1 is no longer split into a lower depth, and a depth for the coding units constituting a current largest coding unit **900** is determined to be d−1 and a partition mode of the current largest coding unit **900** may be determined to be N_(d−1)×N_(d−1). Also, since the maximum depth is d, split information for a coding unit **952** having a depth of d−1 is not set.

A data unit **999** may be a 'minimum unit' for the current largest coding unit. A minimum unit according to the embodiment may be a square data unit obtained by splitting a smallest coding unit having a lowermost depth by 4. By performing the encoding repeatedly, the video encoding apparatus **100** according to the embodiment may select a depth having the minimum encoding error by comparing encoding errors according to depths of the coding unit **900** to determine a depth, and set a corresponding partition type and a prediction mode as an encoding mode of the depth.

As such, the minimum encoding errors according to depths are compared in all of the depths of 0, 1, . . . , d−1, d, and a depth having the least encoding error may be determined as a depth. The depth, the partition mode of the prediction unit, and the prediction mode may be encoded and transmitted as split information. Also, since a coding unit has to be split from a depth of 0 to a depth, only split information of the depth is set to '0', and split information of depths excluding the depth is set to '1'.

The image data and encoding information extractor **220** of the video decoding apparatus **200** according to the embodiment may extract and use a depth and prediction unit information about the coding unit **900** so as to decode the coding unit **912**. The video decoding apparatus **200** according to the embodiment may determine a depth, in which split information is '0', as a depth by using split information according to depths, and may use, for decoding, split information about the corresponding depth.

FIGS. **10**, **11**, and **12** illustrate a relationship between coding units, prediction units, and transformation units, according to various embodiments.

Coding units **1010** are deeper coding units according to depths determined by the video encoding apparatus **100**, in a largest coding unit. Prediction units **1060** are partitions of prediction units of each of the coding units **1010** according to depths, and transformation units **1070** are transformation units of each of the coding units according to depths.

When a depth of a largest coding unit is 0 in the coding units **1010**, depths of coding units **1012** and **1054** are 1, depths of coding units **1014**, **1016**, **1018**, **1028**, **1050**, and **1052** are 2, depths of coding units **1020**, **1022**, **1024**, **1026**, **1030**, **1032**, and **1048** are 3, and depths of coding units **1040**, **1042**, **1044**, and **1046** are 4.

In the prediction units **1060**, some coding units **1014**, **1016**, **1022**, **1032**, **1048**, **1050**, **1052**, and **1054** are obtained by splitting the coding units in the coding units **1010**. That is, partitions **1014**, **1022**, **1050**, and **1054** are a partition mode having a size of 2N×N, partitions **1016**, **1048**, and **1052** are a partition mode having a size of N×2N, and a partition **1032** is a partition mode having a size of N×N. Prediction units and partitions of the coding units **1010** are smaller than or equal to each coding unit.

Transformation or inverse transformation is performed on image data of the coding unit **1052** in the transformation units **1070** in a data unit that is smaller than the coding unit **1052**. Also, the coding units **1014**, **1016**, **1022**, **1032**, **1048**, **1050**, **1052**, and **1054** in the transformation units **1760** are data units different from those in the prediction units **1060** in terms of sizes and shapes. That is, the video encoding apparatus **100** and the video decoding apparatus **200** according to the embodiments may perform intra prediction/motion estimation/motion compensation/and transformation/inverse transformation on an individual data unit in the same coding unit.

Accordingly, encoding is recursively performed on each of coding units having a hierarchical structure in each region of a largest coding unit to determine an optimum coding unit, and thus coding units having a recursive tree structure may be obtained. Encoding information may include split information about a coding unit, partition mode information, prediction mode information, and transformation unit size information. Table 1 below shows the encoding information that may be set by the video encoding apparatus **100** and the video decoding apparatus **200** according to the embodiments.

TABLE 1

Split Information 0 (Encoding on Coding Unit having Size of 2N × 2N and Current Depth of d)					Split Information 1
Prediction Mode	Partition Mode		Size of Transformation Unit		
Intra Inter Skip (Only 2N × 2N)	Symmetrical Partition Mode 2N × 2N 2N × N N × 2N N × N	Asymmetrical Partition Mode 2N × nU 2N × nD nL × 2N nR × 2N	Split Information 0 of Transformation Unit 2N × 2N	Split Information 1 of Transformation Unit N × N (Symmetrical Partition Mode) N/2 × N/2 (Asymmetrical Partition Mode)	Repeatedly Encode Coding Units having Lower Depth of d + 1

The output unit **130** of the video encoding apparatus **100** according to the embodiment may output the encoding information about the coding units having a tree structure, and the image data and encoding information extractor **220** of the video decoding apparatus **200** according to the embodiment may extract the encoding information about the coding units having a tree structure from a received bitstream.

Split information specifies whether a current coding unit is split into coding units of a lower depth. If split information of a current depth d is 0, a depth, in which a current coding unit is no longer split into a lower depth, is a depth, and thus partition mode information, prediction mode information, and transformation unit size information may be defined for the depth. If the current coding unit has to be further split according to the split information, encoding has to be independently performed on four split coding units of a lower depth.

A prediction mode may be one of an intra mode, an inter mode, and a skip mode. The intra mode and the inter mode may be defined in all partition modes, and the skip mode is defined only in a partition mode having a size of 2N×2N.

The partition mode information may indicate symmetrical partition modes having sizes of 2N×2N, 2N×N, N×2N, and N×N, which are obtained by symmetrically splitting a height or a width of a prediction unit, and asymmetrical partition modes having sizes of 2N×nU, 2N×nD, nL×2N, and nR×2N, which are obtained by asymmetrically splitting the height or width of the prediction unit. The asymmetrical partition modes having the sizes of 2N×nU and 2N×nD may be respectively obtained by splitting the height of the prediction unit in 1:3 and 3:1, and the asymmetrical partition modes having the sizes of nL×2N and nR×2N may be respectively obtained by splitting the width of the prediction unit in 1:3 and 3:1.

The size of the transformation unit may be set to be two types in the intra mode and two types in the inter mode. That is, if split information of the transformation unit is 0, the size of the transformation unit may be 2N×2N, which is the size of the current coding unit. If split information of the transformation unit is 1, the transformation units may be obtained by splitting the current coding unit. Also, if a partition mode of the current coding unit having the size of 2N×2N is a symmetrical partition mode, a size of a transformation unit may be N×N, and if the partition mode of the current coding unit is an asymmetrical partition mode, the size of the transformation unit may be N/2×N/2.

The encoding information about coding units having a tree structure according to the embodiment may be assigned to at least one of a coding unit corresponding to a depth, a prediction unit, and a minimum unit. The coding unit corresponding to the depth may include at least one of a prediction unit and a minimum unit containing the same encoding information.

Accordingly, it is determined whether adjacent data units are included in the coding unit corresponding to the same depth by comparing a plurality of pieces of encoding information of the adjacent data units. Also, a corresponding coding unit corresponding to a depth is determined by using encoding information of a data unit, and thus a distribution of depths in a largest coding unit may be inferred.

Accordingly, if a current coding unit is predicted based on encoding information of adjacent data units, encoding information of data units in deeper coding units adjacent to the current coding unit may be directly referred to and used.

In another embodiment, if a current coding unit is predicted based on encoding information of adjacent data units, data units adjacent to the current coding unit may be searched by using encoded information of the data units, and the searched adjacent coding units may be referred for predicting the current coding unit.

FIG. **13** illustrates a relationship between a coding unit, a prediction unit, and a transformation unit, according to encoding mode information of Table 1.

A largest coding unit **1300** includes coding units **1302**, **1304**, **1306**, **1312**, **1314**, **1316**, and **1318** of depths. Here, since the coding unit **1318** is a coding unit of a depth, split information may be set to 0. Partition mode information of the coding unit **1318** having a size of 2N×2N may be set to be one of partition modes including 2N×2N **1322**, 2N×N **1324**, N×2N **1326**, N×N **1328**, 2N×nU **1332**, 2N×nD **1334**, nL×2N **1336**, and nR×2N **1338**.

Transformation unit split information (TU size flag) is a type of a transformation index, and a size of a transformation unit corresponding to the transformation index may be changed according to a prediction unit type or partition mode of the coding unit.

For example, when the partition mode information is set to be one of symmetrical partition modes 2N×2N **1322**, 2N×N **1324**, N×2N **1326**, and N×N **1328**, if the transformation unit split information is 0, a transformation unit **1342** having a size of 2N×2N is set, and if the transformation unit split information is 1, a transformation unit **1344** having a size of N×N may be set.

When the partition mode information is set to be one of asymmetrical partition modes 2N×nU **1332**, 2N×nD **1334**, nL×2N **1336**, and nR×2N **1338**, if the transformation unit split information (TU size flag) is 0, a transformation unit **1352** having a size of 2N×2N may be set, and if the transformation unit split information is 1, a transformation unit **1354** having a size of N/2×N/2 may be set.

The transformation unit split information (TU size flag) described above with reference to FIG. **13** is a flag having a value or 0 or 1, but the transformation unit split information according to an embodiment is not limited to a flag having 1 bit, and the transformation unit may be hierarchically split while the transformation unit split information increases in a manner of 0, 1, 2, 3, etc., according to setting. The transformation unit split information may be an example of the transformation index.

In this case, the size of a transformation unit that has been actually used may be expressed by using the transformation unit split information according to the embodiment, together with a maximum size of the transformation unit and a minimum size of the transformation unit. The video encoding apparatus **100** according to the embodiment may encode maximum transformation unit size information, minimum transformation unit size information, and maximum transformation unit split information. The result of encoding the maximum transformation unit size information, the minimum transformation unit size information, and the maximum transformation unit split information may be inserted into an SPS. The video decoding apparatus **200** according to the embodiment may decode video by using the maximum transformation unit size information, the minimum transformation unit size information, and the maximum transformation unit split information.

For example, (a) if the size of a current coding unit is 64×64 and a maximum transformation unit size is 32×32, (a−1) then the size of a transformation unit may be 32×32 when a TU size flag is 0, (a−2) may be 16×16 when the TU size flag is 1, and (a−3) may be 8×8 when the TU size flag is 2.

As another example, (b) if the size of the current coding unit is 32×32 and a minimum transformation unit size is 32×32, (b−1) then the size of the transformation unit may be 32×32 when the TU size flag is 0. Here, the TU size flag cannot be set to a value other than 0, since the size of the transformation unit cannot be less than 32×32.

As another example, (c) if the size of the current coding unit is 64×64 and a maximum TU size flag is 1, then the TU size flag may be 0 or 1. Here, the TU size flag cannot be set to a value other than 0 or 1.

Thus, if it is defined that the maximum TU size flag is 'MaxTransformSizeIndex', a minimum transformation unit size is 'MinTransformSize', and a transformation unit size is 'RootTuSize' when the TU size flag is 0, then a current minimum transformation unit size 'CurrMinTuSize' that can be determined in a current coding unit may be defined by Equation (1):

$$\text{CurrMinTuSize}=\max(\text{MinTransformSize},\text{RootTuSize}/(2\hat{\ }\text{MaxTransformSizeIndex})) \quad (1)$$

Compared to the current minimum transformation unit size 'CurrMinTuSize' that can be determined in the current coding unit, a transformation unit size 'RootTuSize' when the TU size flag is 0 may denote a maximum transformation unit size that can be selected in the system. In Equation (1), 'RootTuSize/(2^MaxTransformSizeIndex)' denotes a transformation unit size when the transformation unit size 'RootTuSize', when the TU size flag is 0, is split a number of times corresponding to the maximum TU size flag, and 'MinTransformSize' denotes a minimum transformation size. Thus, a smaller value from among 'RootTuSize/(2^MaxTransformSizeIndex)' and 'MinTransformSize' may be the current minimum transformation unit size 'CurrMinTuSize' that can be determined in the current coding unit.

According to an embodiment, the maximum transformation unit size RootTuSize may vary according to the type of a prediction mode.

For example, if a current prediction mode is an inter mode, then 'RootTuSize' may be determined by using Equation (2) below. In Equation (2), 'MaxTransformSize' denotes a maximum transformation unit size, and 'PUSize' denotes a current prediction unit size.

$$\mathrm{RootTuSize}=\min(\mathrm{MaxTransformSize},\mathrm{PUSize}) \quad (2)$$

That is, if the current prediction mode is the inter mode, the transformation unit size 'RootTuSize', when the TU size flag is 0, may be a smaller value from among the maximum transformation unit size and the current prediction unit size.

If a prediction mode of a current partition unit is an intra mode, 'RootTuSize' may be determined by using Equation (3) below. In Equation (3), 'PartitionSize' denotes the size of the current partition unit.

$$\mathrm{RootTuSize}=\min(\mathrm{MaxTransformSize},\mathrm{PartitionSize}) \quad (3)$$

That is, if the current prediction mode is the intra mode, the transformation unit size 'RootTuSize' when the TU size flag is 0 may be a smaller value from among the maximum transformation unit size and the size of the current partition unit.

However, the current maximum transformation unit size 'RootTuSize' that varies according to the type of a prediction mode in a partition unit is just an embodiment, and a factor for determining the current maximum transformation unit size is not limited thereto.

According to the video encoding method based on coding units of a tree structure described above with reference to FIGS. **1** through **13**, image data of a spatial domain is encoded in each of the coding units of the tree structure, and the image data of the spatial domain is reconstructed in a manner that decoding is performed on each largest coding unit according to the video decoding method based on the coding units of the tree structure, so that a video that is formed of pictures and pictures sequences may be reconstructed. The reconstructed video may be reproduced by a reproducing apparatus, may be stored in a storage medium, or may be transmitted via a network.

FIG. **14** illustrates a multiview video system according to an embodiment.

The multiview video system **10** includes: a multiview video encoding apparatus **12** that generates a bitstream by encoding a multiview video image obtained through two or more multiview cameras **11**, a depth image of a multiview image obtained through a depth camera **14**, and camera parameter information related to the multiview cameras **11**, and a multiview video decoding apparatus **13** that decodes the bitstream and provides a decoded multiview video frame in various formats according to a viewer's demand.

The multiview cameras **11** are configured by connecting a plurality of cameras having different views and provide a multiview video image at each frame. In the following description, a color image obtained at each view according to a predetermined color format, such as a YUV format or a YCbCr format, may be referred to as a texture image.

The depth camera **14** provides a depth image that expresses depth information of a scene as an 8-bit image of 256 levels. The number of bits for expressing one pixel of the depth image is not limited to 8 bits and may be changed. The depth camera **14** may measure a distance from a camera to a subject and a background by using infrared ray and provide a depth image having a value proportional or inversely proportional to the distance. As described above, an image of one view includes a texture image and a depth image.

When the multiview video encoding apparatus **12** encodes the multiview texture image and the depth image corresponding thereto and transmits the texture image and the depth image, the multiview video decoding apparatus **13** may provide a 3D effect through an existing stereo image or 3D image by using the multiview texture image and the depth image included in the bitstream and may also combine 3D images of a certain view desired by a viewer and provide the combined image. Information indicating whether information about the depth image is included in a data packet and information indicating whether each data packet is for a texture image, a depth image, or an image type may be included in a bitstream of the multiview video data. According to hardware performance of a receiver side, the multiview video decoding apparatus **13** may decode the multiview video by using the received depth image when the depth image is used to reconstruct the multiview video, and the multiview video decoding apparatus **13** may discard the data packet received in relation to the depth image when hardware of the receiver side does not support the multiview video and thus cannot use the depth image. As such, when the multiview video decoding apparatus **13** cannot display the multiview image, the receiver side may display an image of one view from among the multiview images as a two-dimensional (2D) image.

A data amount to be encoded in the multiview video data increases in proportion to the number of views, and the depth image for realizing a 3D effect needs to be encoded. Thus, as illustrated in FIG. **14**, it is necessary to efficiently compress a large amount of multiview video data so as to implement a multiview video system.

FIG. **15** illustrates texture images and depth images constituting a multiview video.

FIG. **15** illustrates a texture picture v**0** **21** of a first view (view **0**), a depth image picture d**0** **24** corresponding to the texture picture v**0** **21** of the first view (view **0**), a texture picture v**1** **22** of a second view (view **1**), a depth image picture d**1** **25** corresponding to the texture picture v**1** **22** of the second view (view **1**), a texture picture v**2** **23** of a third view (view **2**), and a depth image picture d**2** **26** corresponding to the texture picture v**2** **23** of the third view (view **2**). Although FIG. **15** illustrates the multiview texture pictures (v**0**, v**1**, and v**2**) **21**, **22**, and **23** at three views (view **0**, view **1**, and view **2**) and the corresponding depth images (d**0**, d**1**, and d**2**) **24**, **25**, and **26**, the number of views is not limited thereto and may be changed. The multiview texture pictures (v**0**, v**1**, and v**2**) **21**, **22**, and **23** and the corresponding depth images (d**0**, d**1**, and d**2**) **24**, **25**, and **26** are pictures that are obtained at the same time and have the same picture order count (POC). In the following description, a picture group **1500** having the same POC value of n (n is an integer) as the multiview texture pictures (v**0**, v**1**, and v**2**) **21**, **22**, and **23** and the corresponding depth image pictures (d**0**, d**1**, and d**2**) **24**, **25**, and **26** may be referred to as an n^{th} picture group

1500. A picture group having the same POC may constitute one access unit. Encoding order of access units need not be necessarily the same as capture order (acquisition order) or display order of images. The encoding order of access units may be different from the capture order or the display order by taking into account reference relationship.

A view identifier (ViewId), which is a view order index, may be used to specify the texture image of each view and the view of the depth image. The texture image and the depth image of the same view have the same view identifier. The view identifier may be used to determine the encoding order. For example, the multiview video encoding apparatus **12** may encode a multiview video in ascending order of values of view identifiers. That is, the multiview video encoding apparatus **12** may encode a texture image and a depth image having ViewId of 0 and then encode a texture image and a depth image having ViewId of 1. When the encoding order is determined based on the view identifier as described above, the multiview video decoding apparatus **13** may identify error occurrence or non-occurrence of received data by using the view identifier in an environment where an error easily occurs. However, the encoding or decoding order of images of each view may be changed without depending on the magnitude order of the view identifiers.

Hereinafter, video encoding and decoding apparatuses and video encoding and decoding methods, which can perform sample-wise prediction, will be described with reference to FIGS. **16** through **41**.

Specifically, intra prediction encoding and decoding apparatuses and intra prediction encoding and decoding methods, which perform intra prediction of a current sample based on an already predicted adjacent sample, will be described with reference to FIGS. **16** through **24**. Then, intra prediction encoding and decoding apparatuses and intra prediction encoding and decoding methods, which perform intra prediction of a current sample based on an already reconstructed sample, will be described with reference to FIGS. **29** through **41**.

FIG. **16** illustrates a block diagram of a video encoding apparatus that can perform sample-wise prediction based on an already predicted adjacent sample.

The video encoding apparatus **1600** may include a splitter **1610**, a predictor **1620**, and an encoder **1630**. The video encoding apparatus **1600** may include a central processor (not illustrated) that collectively controls the splitter **1610**, the predictor **1620**, and the encoder **1630**. Alternatively, the splitter **1610**, the predictor **1620**, and the encoder **1630** may be driven by their individual processors (not illustrated) that interoperate with one another to collectively control the video encoding apparatus **1600**. Alternatively, the splitter **1610**, the predictor **1620**, and the encoder **1630** may be controlled under control of an external processor (not illustrated) disposed outside the video encoding apparatus **1600**.

The video encoding apparatus **1600** may include one or more data storages (not illustrated) that store input and output data of the splitter **1610**, the predictor **1620**, and the encoder **1630**. The video encoding apparatus **1600** may include a memory controller (not illustrated) that manages data input and output of the data storages (not illustrated).

In order to output a result of video encoding, the video encoding apparatus **1600** may operate in connection with an internal video encoding processor or an external video encoding processor, so as to perform a video encoding operation including prediction. The internal video encoding processor of the video encoding apparatus **1600** may be an independent processor for performing a video encoding operation. Also, the video encoding apparatus **1600**, the central processor, or a graphic processor may include a video encoding processing module to perform a basic video encoding operation.

The video encoding apparatus **1600** may be included in the video encoding apparatus **100** of FIG. **1**. Specifically, the splitter **1610** may be included in the largest coding unit splitter **110** and the coding unit determiner **120**, the predictor **1620** may be included in the intra predictor **420**, and the encoder **1630** may be included in the transformer **425**, the quantizer **430**, and the entropy encoder **435**. Therefore, the descriptions provided above with reference to FIGS. **1** and **4** will be omitted.

The splitter **1610** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded.

Specifically, the block may be a largest coding unit split from an image based on size information of a coding unit for determining a maximum size of the coding unit. The largest coding unit including the coding units of the tree structure may be variously referred to as coding tree unit, coding block tree, block tree, root block tree, coding tree, coding root, or tree trunk.

Alternatively, the block may be a coding unit split from a largest coding unit based on coding unit split information indicating whether or not a coding unit is split.

Alternatively, the block may be a prediction unit split from a coding unit of a final depth, that is, a coding unit that cannot be split any more. For example, the block may include a coding unit of a final depth, and a first prediction unit and a second prediction unit obtained by splitting at least one of a height and a width of the coding unit of the final depth, based on a partition mode. The prediction unit may be a data unit obtained by splitting the coding unit of the final depth, and the prediction unit may have the same size as that of the coding unit of the final depth. The partition mode may indicate a type of at least one prediction unit split from the coding unit. For example, when the partition mode indicates 2N×N, the splitter **1610** may split the coding unit of the final depth having a size of 2N×2N into two prediction units each having a size of 2N×N.

Alternatively, the block may be a transformation unit split from a coding unit of a final depth. For example, the block may be a transformation unit split from a transformation unit to a quad tree structure based on transformation unit split information.

The type of the block may be a square, a rectangle, or any geometric shape. The block is not limited to a data unit having a constant size.

The predictor **1620** obtains a prediction value of a current sample by using at least one sample predicted earlier than the current sample in a current block split from an image. Specifically, the predictor **1620** may predict the current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample and being adjacent to the current sample in a vertical direction.

The encoder **1630** encodes a residual value of the current sample. Specifically, the encoder **1630** may obtain a residual value between an original value of the current sample and a prediction value of the current sample obtained by the predictor **1620**, transform the residual value of the current sample, perform entropy encoding on the transformed residual value, and output the entropy-encoded residual value in a bitstream.

FIG. **17** illustrates a block diagram of a video decoding apparatus that can perform sample-wise prediction based on an already predicted adjacent sample.

The video decoding apparatus **1700** may include a splitter **1710**, a predictor **1720**, and a decoder **1730**. The video decoding apparatus **1700** may include a central processor (not illustrated) that collectively controls the splitter **1710**, the predictor **1720**, and the decoder **1730**. Alternatively, the splitter **1710**, the predictor **1720**, and the decoder **1730** may be driven by their individual processors (not illustrated) that interoperate with one another to collectively control the video decoding apparatus **1700**. Alternatively, the splitter **1710**, the predictor **1720**, and the decoder **1730** may be controlled under control of an external processor (not illustrated) disposed outside the video decoding apparatus **1700**.

The video decoding apparatus **1700** may include one or more data storages (not illustrated) that store input and output data of the splitter **1710**, the predictor **1720**, and the decoder **1730**. The video decoding apparatus **1700** may include a memory controller (not illustrated) that manages data input and output of the data storages (not illustrated).

In order to output a result of video decoding, the video decoding apparatus **1700** may operate in connection with an internal video decoding processor or an external video decoding processor, so as to perform the video decoding operation including filtering. The internal video encoding processor of the video decoding apparatus **1700** may be an independent processor for performing a video decoding operation. Also, the video decoding apparatus **1700**, the central processor, or a graphic processor may include a video decoding processing module to perform a basic video decoding operation.

The video decoding apparatus **1700** may be included in the video decoding apparatus **200** of FIG. **2**. Specifically, the splitter **1710** may be included in the receiver **210**, and the predictor **1720** and the decoder **1730** may be included in the image data decoder **230**. Therefore, the descriptions provided above with reference to FIG. **2** will be omitted.

The splitter **1710** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded.

The predictor **1720** obtains a prediction value of a current sample by using a sample predicted earlier than the current sample in a current block split from an image. Specifically, the predictor **1720** may predict the current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample and being adjacent to the current sample in a vertical direction.

The decoder **1730** decodes an image. Specifically, the decoder **1730** may reconstruct the image by using the residual value of the current sample obtained from the bitstream and the prediction value of the current sample obtained by the predictor **1720**.

FIG. **18**A illustrates an operation of sample-wise prediction to predict a current sample based on a sample already predicted in a current block.

The predictors **1620** and **1720** may predict a current sample C based on at least one of samples A**1**, A**2**, and A**3** adjacent to the current sample C in a current block **1800** split from an image and predicted earlier than the current sample C.

At least one adjacent sample used for predicting the current sample C from among the samples adjacent to the current sample C may change according to a prediction direction of the current block **1800** and a position of the current sample C in the current block **1800**. For example, as illustrated in FIG. **18**A, if the prediction is performed from a left upper side to a right lower side of the current block **1800**, the current sample C may be predicted based on a prediction value of a sample A**1** adjacent to a left side of the current sample C, a prediction value of a sample A**2** adjacent to an upper side of the current sample C, and a prediction value of a sample A**3** adjacent to a left upper side of the current sample C. Specifically, the predictors **1620** and **1720** may obtain a prediction value of the current sample C based on Equation 1 below:

$$pDest[i,j]=(w_L(pDest[i,j])\cdot pDest[i,j-1]+w_A(pDest[i,j])\cdot pDest[i\cdot 1,j]+w_{AL}(pDest[i,j])\cdot pDest[i-1,j-1]+\text{offset})\gg\text{shift(weighted average)};$$

$$(w_L(\mathrm{pDest}[i,j])+w_A(\mathrm{pDest}[i,j])+w_{AL}(pDest[i,j]))=(1\ll\text{shift});$$

$$\text{offset}=(1\ll(\text{shift}-1));$$

$$0\le i\le H-1;0\le j\le W-1; \quad \text{[Equation 1]}$$

In Equation 1, pDest[i, j] may denote a sample of an i^{th} row and a j^{th} column in the current block. For example, the current sample C, the sample A**1**, the sample A**2**, and the sample A**3** in FIG. **18**A may correspond to pDest[1,1], pDest[0,1], pDest[1,0], and pDest[0,0], respectively. wL, wA, and wAL may denote weights applied to adjacent samples used to predict the current sample. The weights will be described below in detail with reference to FIGS. **21**, **22**, and **23**. Also, shift and offset may correspond to parameters for compensating the weights. H may denote a height of the current block **1800**, and W may denote a width of the current block **1800**.

When the current sample is located at a boundary of the current block **1800**, a sample used to predict the current sample may be a reference sample **1810** of the current block **1800**. The reference sample **1810** may include a reconstructed sample included in at least one previous block reconstructed earlier than the current block **1800**. Also, the reference sample **1810** may be adjacent to the boundary of the current block **1800**. For example, as illustrated in FIG. **18**A, if the prediction is performed from a left upper side to a right lower side of the current block **1800**, the sample A**3** may be predicted based on a reconstruction value of a reference sample R**1** adjacent to a left side of the Sample A**3**, a reconstruction value of a reference sample R**2** adjacent to an upper side of the sample A**3**, and a reconstruction value of a reference sample R**3** adjacent to a left upper side of the sample A**3**.

If the reference sample **1810** is unavailable, the predictors **1620** and **1720** may perform reference sample padding. For example, the predictors **1620** and **1720** may fill an unavailable reference sample by using an available reference sample closest to the unavailable reference sample. As another example, if all reference samples are unavailable, the predictors **1620** and **1720** may fill all reference samples with a median value of an expressible brightness value range. As another example, the predictors **1620** and **1720** may perform reference sample padding based on Equation 2 below:

left boundary: $i=-1; 0 \le j \le H-1;$ (1)

$$p\mathrm{Dest}[i,j]=\Sigma f[m]\cdot p\mathrm{Src}[-1,j+m];$$

top boundary: $j=-1; 0 \le i \le W-1;$ (2)

$$p\mathrm{Dest}[i,j]=\Sigma f[m]\cdot p\mathrm{Src}[i+m,-1];$$

corner: $i=-1; j=-1;$ (3)

$$p\mathrm{Dest}[i,j]=(p\mathrm{Dest}[0,-1]+p\mathrm{Dest}[-1,0]+1)>>1; \quad \text{[Equation 2]}$$

In Equation 2, pSrc[i, j] may denote a sample included in at least one previous block reconstructed earlier than the current block. pDest[i, −1] may denote reference samples adjacent to an upper side of the current block **1800**, pDest [−1, j] may denote reference samples adjacent to a left side of the current block **1800**, and pDest[−1, −1] may denote a reference sample adjacent to a left upper side of the current block **1800**. For example, the reference sample R**1**, the reference sample R**2**, and the reference sample R**3** may correspond to pDest[−1.0], pDest[0, −1], and pDest[−1, −1], respectively. Also, f[m] may correspond to a filter function, and m may correspond to an index indicating a filter coefficient. Therefore, the reference sample **1810** of the current block **1800** may be filled by filtering a reconstruction value of at least one sample included in a previous block. Characteristics of the filter function f[m] may be changed based on characteristics of an image. For example, the filter function f[m] may correspond to a low-pass filter, a high-pass filter, a band-pass filter, or the like. Also, the reference sample R**3** may be filled with an average value of the reference sample R**1** and the reference sample R**2** closest to the reference sample R**3**.

If the current sample is predicted based on the sample already predicted in the same block, the encoding and decoding apparatuses and the encoding and decoding methods may perform adaptive prediction according to the position of the current sample, and encoding and decoding performance may be improved.

FIG. **18**B illustrates an operation of another sample-wise prediction to predict a current sample based on a sample already predicted in a current block.

The predictors **1620** and **1720** may predict a current sample C based on at least one of samples A**1**, A**2**, A**3**, and A**8** adjacent to the current sample C in a current block **1800** split from an image and predicted earlier than the current sample C.

At least one adjacent sample used to predict the current sample C from among the samples adjacent to the current sample C may change according to a prediction direction of the current block **1800** and a position of the current sample C in the current block **1800**. For example, as illustrated in FIG. **18**B, if the prediction is performed from a left upper side to a right lower side of the current block **1800**, the current sample C may be predicted based on a prediction value of the sample A**1** adjacent to a left side of the current sample C, a prediction value of the sample A**2** adjacent to an upper side of the current sample C, a prediction value of the sample A**3** adjacent to a left upper side of the current sample C, and a prediction value of the sample A**8** adjacent to a right upper side of the current sample C. Specifically, the predictors **1620** and **1720** may obtain a prediction value of the current sample C based on Equation 3 below:

$$p\mathrm{Des}[i,j]=w_L(p\mathrm{Dest}[i,j])\cdot p\mathrm{Dest}[i,j-1]+w_A(p\mathrm{Dest}[i,j])\cdot p\mathrm{Dest}[i-1,j]+w_{AL1}(p\mathrm{Dest}[i,j])\cdot p\mathrm{Dest}[i-1,j-1]+w_{AL2}(p\mathrm{Dest}[i,j])\cdot p\mathrm{Dest}[i-1,j+1]+\mathrm{offset})>>\mathrm{shift} \text{ (weighted average);}$$

$$w_L(p\mathrm{Dest}[i,j])+w_A(p\mathrm{Dest}[i,j])+w_{AL1}(p\mathrm{Dest}[i,j])+w_{AL2}(p\mathrm{Dest}[i,j]))=(1<<\mathrm{shift});$$

$$\mathrm{offset}=(1<<(\mathrm{shift}-1));$$

$$0 \le i \le H-1; 0 \le j \le W-1; \quad \text{[Equation 3]}$$

In Equation 3, pDest[i, j] may denote a sample of an i^{th} row and a j^{th} column in the current block. For example, the current sample C, the sample A**1**, the sample A**2**, the sample A**3**, and the sample A**8** in FIG. **18**B may correspond to pDest[1,1], pDest[0,1], pDest[1,0], pDest[0,0], and pDest[0, 2], respectively. wL, wA, wAL**1**, and wAL**2** may denote weights applied to adjacent samples used to predict the current sample. The weights will be described below in detail with reference to FIGS. **21**, **22**, and **23**. Also, shift and offset may correspond to parameters for compensating the weights. H may denote a height of the current block **1800**, and W may denote a width of the current block **1800**.

When the current sample is located at a boundary of the current block **1800**, a sample used to predict the current sample may be a reference sample **1810** of the current block **1800**. The reference sample **1810** may include a reconstructed sample included in at least one previous block reconstructed earlier than the current block **1800**. Also, the reference sample **1810** may be adjacent to the boundary of the current block **1800**. For example, as illustrated in FIG. **18**A, if the prediction is performed from a left upper side to a right lower side of the current block **1800**, the sample A**3** may be predicted based on a reconstruction value of the reference sample R**1** adjacent to a left side of the Sample A**3**, a reconstruction value of the reference sample R**2** adjacent to an upper side of the sample A**3**, a reconstruction value of the reference sample R**3** adjacent to a left upper side of the sample A**3**, and a reconstruction value of a reference sample A**4** adjacent to a right upper side of the sample A**3**.

FIG. **19** illustrates adjacent samples available for predicting a current sample.

As described above, the current sample C may be predicted by using at least one of the adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C. The adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C may include samples closest to the current sample C, such as the samples A**1** and A**4** adjacent to the current sample C in a horizontal direction and the samples A**2** and A**5** adjacent to the current sample C in a vertical direction. Also, the adjacent samples of the current sample C may include samples adjacent to the current sample C in a diagonal direction, such as the sample A**3** adjacent to a left upper side of the current sample C, the sample A**6** adjacent to a right lower side of the current sample C, the sample A**7** adjacent to a left lower side of the current sample C, and the sample A**8** adjacent to a right upper side of the current sample C.

The predictors **1620** and **1720** may determine at least one sample for predicting the current sample C from among the adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C within the current block **1800** and reference samples **1950** of the current block **1800** outside the current block **1800** For example, as illustrated in FIG. **19**, when the current sample C in the current block **1800** is not located at the boundary of the current block **1800** having a size of 4×4, the predictors **1620** and **1720** may determine at least one adjacent sample for predicting the current sample C from among a left adjacent sample A**1**, an upper adjacent sample A**2**, a left upper adjacent sample A**3**, a right adjacent sample A**4**, a lower adjacent sample A**5**, a right lower adjacent sample A**6**, a left lower adjacent sample A**7**, and a right upper adjacent sample A**8**, which are located in the current block **1800**. In another example, when the current sample C is located at the boundary of the current block **1800** like the sample A3, the predictors **1620** and **1720** may determine at least one adjacent sample for predicting the current sample C from among the reference samples **1950** of the current block **1800**. The prediction using the reference sample will be described in detail with reference to FIGS. **23** through **26**.

The predictors **1620** and **1720** may determine at least one adjacent sample for predicting the current sample C from among the adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C based on the prediction order in the current block **1800**. Since the current sample c can be predicted by using the sample whose prediction order is ahead of the prediction order of the current sample C, the adjacent sample available for predicting the current sample may change according to the prediction order in the current block.

For example, when horizontal prediction **1910** is sequentially performed from an uppermost row (i=0) to a lowermost row (i=3) in the current block **1800** having a size of 4×4, at least one of the left adjacent sample A**1**, the upper adjacent sample A**2**, the left upper adjacent sample A**3**, and the right upper adjacent sample A**8** of the current sample C may be used to predict the current sample C.

In another example, when vertical prediction **1920** is sequentially performed from a leftmost column (j=0) to a rightmost column (j=3) in the current block **1800** having a size of 4×4, at least one of the left adjacent sample A**1**, the upper adjacent sample A**2**, the left upper adjacent sample A**3**, and the left lower adjacent sample A**7** of the current sample C may be used to predict the current sample C.

In another example, when left lower diagonal prediction **1930** is sequentially performed from a leftmost upper sample A**3** to a rightmost lower sample E in the current block **1800** having a size of 4×4, at least one of the left adjacent sample A**1**, the upper adjacent sample A**2**, the left upper adjacent sample A**3**, and the right upper adjacent sample A**8** of the current sample C may be used to predict the current sample C.

In another example, when right upper diagonal prediction **1940** is sequentially performed from a rightmost lower sample S to a leftmost upper sample A**3** in the current block **1800** having a size of 4×4, at least one of the right adjacent sample A**4**, the lower adjacent sample A**5**, the right lower adjacent sample **63**, and the left lower adjacent sample A**7** of the current sample C may be used to predict the current sample C.

The prediction direction of the current block **1800** is not limited to the horizontal prediction **1910**, the vertical prediction **1920**, the left lower diagonal prediction **1930**, and the right upper diagonal prediction **1940** of FIG. **19**. The samples used to predict the current sample C may change based on the position of the current sample C in the current block **1800** and the prediction direction of the current block **1800**.

FIG. **20** illustrates weights applied to adjacent samples.

The predictors **1620** and **1720** may predict the current sample C by using the value obtained by applying the weight to the adjacent sample.

The predictors **1620** and **1720** may predict the current sample C by applying a preset weight to the adjacent sample of the current sample C. For example, the predictors **1620** and **1720** may predict the current sample C by applying the same weight to the sample adjacent to the current sample C in a horizontal direction and the sample adjacent to the current sample C in a vertical direction.

The predictors **1620** and **1720** may determine the weight applied to the adjacent samples based on a direction in which the adjacent sample of the current sample C is adjacent to the current sample C. The weight applied to the sample adjacent to the current sample C in a horizontal direction and the weight applied to the sample adjacent to the current sample C in a vertical direction may be independent of each other. The predictors **1620** and **1720** may obtain a vertical gradient in the current block **1800** and determine the weight applied to the sample adjacent to the current sample C in a horizontal direction based on the obtained vertical gradient. The vertical gradient of the current block **1800** may denote a numerical index indicating whether samples in the current block **1800** has consistency in a vertical direction. For example, the predictors **1620** and **1720** may obtain the vertical gradient in the current block **1800** by using a difference value of samples adjacent in a vertical direction in the current block **1800**. The predictors **1620** and **1720** may obtain a vertical gradient in the current block **1800** and determine the weight applied to the sample adjacent to the current sample C in a horizontal direction based on the obtained vertical gradient. The horizontal gradient of the current block **1800** may denote a numerical index indicating whether samples in the current block **1800** has consistency in a horizontal direction. For example, the indictors **1620** and **1720** may obtain the horizontal gradient in the current block **1800** by using a difference value of samples adjacent in a horizontal direction in the current block **1800**. The vertical gradient and the horizontal gradient of the current block **1800** will be described in detail with reference to FIGS. **21** through **22**.

For example, when the horizontal prediction **1910**, the vertical prediction **1920**, or the left lower diagonal prediction **1930** are performed on the current block **1800**, the predictors **1620** and **1720** may predict the current sample C by using at least one of a value obtained by applying a first weight wA(C) to a left adjacent sample A**1** of the current sample C, a value obtained by applying a second weight wL(C) to an upper adjacent sample A**2** of the current sample C, and a value obtained by applying a third weight wAL(C) to a left upper sample A**3** of the current sample C.

The predictors **1620** and **1720** may predict the current sample C by using the preset first weight wA(C), the preset second weight wL(C), and the preset third weight wAL(C). For example, the predictors **1620** and **1720** may set the first weight wA(C), the second weight wL(C), and the third weight wAL(C) of Equation 1 based on Equation 4 below:

$$w_L(p\mathrm{Dest}[i,j])=w_A(p\mathrm{Dest}[i,j])=w;$$

$$(w_L(\mathrm{pDest}[i,j])+w_A(\mathrm{pDest}[i,j])+w_{AL}(\mathrm{pDest}[i,j])) \\ =\ll \mathrm{shift});$$

$$w_{AL}=2^{shift}-2w; \qquad \text{[Equation 4]}$$

In Equation 4, shift may be the same as shift of Equation 1 and may be a parameter for compensating the weights applied to the adjacent samples A**1**, A**2**, and A**3** of the current sample C. Specifically, the predictors **1620** and **1720** may preset the first weight wA(C) and the second weight wL(C) to have the same value and set the third weight wAL(C) based on the first weight wL(C), the second weight WA(C), and the weight compensation parameter shift.

The predictors **1620** and **1720** may set the first weight wA(C), the second weight wL(C), and the third weight wAL(C) based on a direction in which the adjacent sample of the current sample C is adjacent to the current sample C. For example, the predictors **1620** and **1720** may set the first weight wA(C), the second weight wL(C), and the third weight wAL(C) based on Equation 5 below:

$$w_L(p\mathrm{Dest}[i,j]) \propto p\mathrm{Dest}[i,j-1]-p\mathrm{Dest}[i-1,j-1];$$

$$w_A(p\mathrm{Dest}[i,j]) \propto p\mathrm{Dest}[i,-1j]-p\mathrm{Dest}[i-1,j-1];$$

$$(w_L(p\mathrm{Dest}[i,j])+w_A(p\mathrm{Dest}[i,j])+w_{AL}(p\mathrm{Dest}[i,j]))=(1<<\mathrm{shift});$$

$$w_{AL}(p\mathrm{Dest}[i,j])=2^{shift}-w_L(p\mathrm{Dest}[i,j])-w_A(p\mathrm{Dest}[i,j]); \quad \text{[Equation 5]}$$

Specifically, the predictors **1620** and **1720** may determine the first weight wA(C) applied to the left adjacent sample A**1** of the current sample C based on a vertical gradient between the left adjacent sample A**3** of the current sample C and the left upper adjacent sample A**3** of the current sample C. As the vertical gradient value of the current block **1800** increases, the vertical consistency of the samples in the current block **1800** decreases. Thus, the first weight wA(C), which is the horizontal weight, may increase. Also, the predictors **1620** and **1720** may determine the second weight wL(C) applied to the upper sample A**2** of the current sample C based on a horizontal gradient between the upper adjacent sample A**2** of the current sample C and the left upper adjacent sample A**3** of the current sample C. As the horizontal gradient value of the current block **1800** increases, the horizontal consistency of the samples in the current block **1800** decreases. Thus, the second weight wL(C), which is the vertical weight, may increase. In Equation 5, shift may be the same as shift of Equation 1 and may be a parameter for compensating the weights applied to the adjacent samples A**1**, A**2**, and A**3** of the current sample C. Also, the predictors **1620** and **1720** may set the third weight wAL(C) based on the first weight wL(C), the second weight wA(C), and the weight compensation parameter shift.

As in Equation 3, when a plurality of diagonal adjacent samples A**3** and A**8** that are adjacent to the current sample C in a diagonal direction are used to predict the current sample C, the predictors may apply the same weight to the diagonal weight adjacent samples A**3** and A**8**. For example, the weight wAL**1** applied to the sample A**3** adjacent to the current sample C in a left upper diagonal direction and the weight wAL**2** applied to the sample A**8** adjacent to the current sample C in a right upper diagonal direction may be set to have the same value.

FIG. **21** illustrates the first weight applied to the sample adjacent to the current sample in the horizontal direction.

The first weight wA(C) may be proportional to a difference value between the sample A**1** predicted earlier than the current sample C in the current block **1800** and being adjacent to the current sample C in the horizontal direction and the sample A**3** predicted earlier than the current sample C in the current block **1800** and being adjacent to the current sample in the diagonal direction.

For example, when the prediction is performed from a left upper side to a right lower side of the current block **1800** as illustrated in FIG. **18**A, the predictors **1620** and **1720** may obtain a vertical gradient based on the left adjacent sample A**1** of the current sample C and the left upper adjacent sample A**3** of the current block C and obtain the first weight wA(C) applied to the left adjacent sample A**1** of the current sample C based on the obtained vertical gradient. As the vertical gradient of the current block **1800** increases, the first weight wA(C) may increase.

The vertical gradient of the current block **1800** may change according to a prediction direction of the current block **1800**. Specifically, the vertical gradient of the current block **1800** may be obtained by using samples predicted earlier than the current sample C in the current block **1800**. For example, the vertical gradient may be a difference between the left adjacent sample A**1** and the left upper adjacent sample A**3** of the current sample C, a difference between the left adjacent sample A**1** and the left lower adjacent sample A**7**, a difference between the upper adjacent sample A**2** and the lower adjacent sample A**5**, a difference between the right adjacent sample A**4** and the right upper adjacent sample A**8**, or a difference between the right adjacent sample A**4** and the right lower adjacent sample A**6**, according to the prediction direction of the current block **1800**.

FIG. **22** illustrates the second weight applied to the sample adjacent to the current sample in the vertical direction.

The second weight wL(C) may be proportional to a difference value between the sample A**2** predicted earlier than the current sample C in the current block **1800** and being adjacent to the current sample C in the vertical direction and the sample A**3** predicted earlier than the current sample C in the current block **1800** and being adjacent to the current sample in the diagonal direction.

For example, when the prediction is performed from a left upper side to a right lower side of the current block **1800** as illustrated in FIG. **18**A, the predictors **1620** and **1720** may obtain a horizontal gradient based on the upper adjacent sample A**2** of the current sample C and the left upper adjacent sample A**3** of the current block C and obtain the second weight wL(C) applied to the upper adjacent sample A**2** of the current sample C based on the obtained horizontal gradient. As the horizontal gradient of the current block **1800** increases, the second weight wL(C) may increase.

The horizontal gradient of the current block **1800** may change according to a prediction direction of the current block **1800**. Specifically, the horizontal gradient of the current block **1800** may be obtained by using samples predicted earlier than the current sample C in the current block **1800**. For example, the horizontal gradient may be a difference between the upper adjacent sample A**2** and the left upper adjacent sample A**3** of the current sample C, a difference between the upper adjacent sample A**2** and the right upper adjacent sample A**8**, a difference between the left adjacent sample A**1** and the right adjacent sample A**4**, a difference between the left lower adjacent sample A**7** and the lower upper adjacent sample A**5**, or a difference between the lower adjacent sample A**5** and the right lower adjacent sample A**6**, according to the prediction direction of the current block **1800**.

FIG. **23** illustrates an operation of predicting a sample located at a vertical boundary of a current block.

A sample located at a vertical boundary **2310** of a current block **1800** may be predicted by using at least one reference sample **2320** adjacent to the vertical boundary **2310** of the current block **1800**. Specifically, the sample located at the vertical boundary **2310** of the current block **1800** may be predicted by using a value obtained by applying a weight to at least one reference sample **2320** outside the current block **1800** and adjacent to the sample in the horizontal direction.

For example, when the left adjacent sample A**1** (hereinafter, referred to as an A**1** sample) of the current sample C is located at the vertical boundary **2310** on the left side of the current block **1800**, the A**1** sample may be predicted by using at least one of a value obtained by applying a fourth weight wA(A**1**) to a first reference sample R**1** (hereinafter, referred to as an R**1** sample) outside the current block **1800** and adjacent to the A1 sample in the horizontal direction and a value obtained by applying a fifth weight wL(A1) to an upper adjacent sample A3 (hereinafter, referred to as an A3 sample) of the current sample C.

The fourth weight wA(A1) may be obtained based on the vertical gradient of the current block **1800**. For example, the fourth weight wA(A1) may be proportional to a difference value between a second reference sample R2 (hereinafter, referred to as an R2 sample) outside the current block **1800** and adjacent to a left upper side of the A1 sample and the R1 sample.

Also, the fifth weight wL(A1) may be obtained based on the horizontal gradient of the current block **1800**. For example, the fifth weight wL(A1) may be proportional to a difference value between the A3 sample and the R2 sample.

Also, the predictors **1620** and **1720** may determine a sixth weight wAL(A1) based on the fourth weight wA(A1) and the fifth weight wL(A1) and predict the A1 sample by using the value obtained by applying the sixth weight wAL(A1) to the R2 sample.

FIG. **24** illustrates an operation of predicting a sample located at a horizontal boundary of a current block.

A sample located at a horizontal boundary **2420** of a current block **1800** may be predicted by using at least one reference sample **2421** adjacent to the horizontal boundary **2420** of the current block **1800**. Specifically, the sample located at the horizontal boundary **2420** of the current block **1800** may be predicted by using a value obtained by applying a weight to at least one reference sample **2410** outside the current block **1800** and adjacent to the sample in the vertical direction.

For example, when an upper adjacent sample A2 (hereinafter, referred to as an A2 sample) of the current sample C is located at the horizontal boundary **2420** on an upper side of the current block **1800**, the A2 sample may be predicted by using at least one of a value obtained by applying a fourth weight wA(A2) to a first reference sample R1 (hereinafter, referred to as an R1 sample) outside the current block **1800** and adjacent to the A2 sample in the vertical direction and a value obtained by applying a fifth weight wL(A2) to a left upper adjacent sample A3 (hereinafter, referred to as an A3 sample) of the current sample C.

The fourth weight wA(A2) may be obtained based on a vertical gradient of the current block **1800**. For example, the fourth weight wA(A2) may be proportional to a difference value between a second reference sample R2 (hereinafter, referred to as an R2 sample) outside the current block **1800** and adjacent to a left upper side of the A2 sample and the R1 sample.

Also, the fifth weight wL(A2) may be obtained based on the horizontal gradient of the current block **1800**. For example, the fifth weight wL(A2) may be proportional to a difference value between the R1 sample and the R2 sample.

Also, the predictors **1620** and **1720** may determine a sixth weight wAL(A2) based on the fourth weight wA(A2) and the fifth weight wL(A2) and predict the A2 sample by using the value obtained by applying the sixth weight wAL(A) to the R2 sample.

FIG. **25** illustrates an operation of predicting a sample located at a corner of a current block.

A sample located at a corner of a current block **1800** may be predicted by using at least one reference sample **2510** adjacent to a horizontal boundary **2420** or a vertical boundary **2310** of the current block **1800**. Specifically, the sample located at the corner of the current block **1800** may be predicted by using a value obtained by applying a weight to at least one reference sample **2510** outside the current block **1800** and adjacent to the sample in the vertical direction or the horizontal direction.

For example, when a left upper adjacent sample A3 (hereinafter, referred to as an A3 sample) of the current sample C is located at a corner where the horizontal boundary **2420** on an upper side of the current block **1800** and the vertical boundary **2310** on a left side of the current block **1800** meet each other, the A3 sample may be predicted by using at least one of a value obtained by applying a fourth weight wA(A3) to a first reference sample R1 (hereinafter, referred to as an R1 sample) outside the current block **1800** and adjacent to the A3 sample in a horizontal direction and a value obtained by applying a fifth weight wL(A3) to a second reference sample R2 (hereinafter, referred to as an R2 sample) outside the current block **1800** and adjacent to the A3 sample in a vertical direction.

The fourth weight wA(A3) may be obtained based on a vertical gradient of the current block **1800**. For example, the fourth weight wA(A3) may be proportional to a difference value between a third reference sample R3 (hereinafter, referred to as an R3 sample) outside the current block **1800** and adjacent to a left upper side of the A3 sample and the R1 sample.

Also, the fifth weight wL(A3) may be obtained based on a horizontal gradient of the current block **1800**. For example, the fifth weight wL(A3) may be proportional to a difference value between the R1 sample and the R3 sample.

Also, the predictors **1620** and **1720** may determine a sixth weight wAL(A3) based on the fourth weight wA(A3) and the fifth weight wL(A3) and predict the A3 sample by using the value obtained by applying the sixth weight wAL(A) to the R3 sample.

FIG. **26** illustrates an operation of performing reference sample padding.

As described above with reference to FIG. **18**A, if the reference sample is unavailable, the predictors **1620** and **1720** may perform reference sample padding. For example, if a reference sample R3 adjacent to the corner where the horizontal boundary **2420** on the upper side of the current block **1800** and the vertical boundary **2310** on the left side of the current block **1800** meet each other (hereinafter, referred to as an R3 reference sample) is unavailable, the R3 reference sample may be filled with an average value of the R1 reference sample and the R2 reference sample closest to the R3 reference sample.

FIG. **27** is a flowchart of a video encoding method that can perform sample-wise prediction based on an already predicted adjacent sample.

In operation **2710**, a video encoding method **2700** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded. The type of the block may be a square, a rectangle, or any geometric shape. The block is not limited to a data unit having a constant size. Operation **2710** may be performed by the splitter **1610** of the video encoding apparatus **1600**.

In operation **2720**, the video encoding method **2700** obtains a prediction value of a current sample by using at least one sample predicted earlier than the current sample in a current block split from an image. Specifically, the current sample may be predicted by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample and being adjacent to the current sample in a vertical direction. Operation **2720** may be performed by the predictor **1620** of the video encoding apparatus **1600**.

In operation **2730**, the video encoding method **2700** encodes a residual value of the current sample. Specifically, the video encoding method **2700** may obtain a residual value between an original value of the current sample and a prediction value of the current sample obtained in operation **2730**, transform the residual value of the current sample, perform entropy encoding on the transformed residual value, and output the entropy-encoded residual value in a bitstream. Operation **2730** may be performed by the encoder **1630** of the video encoding apparatus **1600**.

FIG. **28** is a flowchart of a video decoding method that can perform sample-wise prediction based on an already predicted adjacent sample.

In operation **2810**, a video decoding method **2800** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded. The type of the block may be a square, a rectangle, or any geometric shape. The block is not limited to a data unit having a constant size. Operation **2810** may be performed by the splitter **1710** of the video decoding apparatus **1700**.

In operation **2820**, the video decoding method **2800** obtains a prediction value of a current sample by using at least one sample predicted earlier than the current sample in a current block split from an image. Specifically, the current sample may be predicted by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample and being adjacent to the current sample in a vertical direction. Operation **2820** may be performed by the predictor **1720** of the video decoding apparatus **1700**.

In operation **2830**, the video decoding method **2800** decodes the image Specifically, the video decoding method may reconstruct the image by using the residual value of the current sample obtained from the bitstream and the prediction value of the current sample obtained in operation **2820**. Operation **2830** may be performed by the decoder **1730** of the video decoding apparatus **1700**.

FIG. **29** illustrates a block diagram of a video encoding apparatus that can perform sample-wise prediction based on an already reconstructed sample.

A video encoding apparatus **2900** may include a splitter **2910**, a candidate selector **2920**, a predictor **2930**, and an encoder **2940**. The video encoding apparatus **2900** may include a central processor (not illustrated) that collectively controls the splitter **2910**, the candidate selector **2920**, the predictor **2930**, and the encoder **2940**. Alternatively, the splitter **2910**, the candidate selector **2920**, the predictor **2930**, and the encoder **2940** may be driven by their individual processors (not illustrated) that interoperate with one another to collectively control the video encoding apparatus **2900**. Alternatively, the splitter **2910**, the candidate selector **2920**, the predictor **2930**, and the encoder **2940** may be controlled under control of an external processor (not illustrated) disposed outside the video encoding apparatus **2900**.

The video encoding apparatus **2900** may include one or more data storages (not illustrated) that store input and output data of the splitter **2910**, the candidate selector **2920**, the predictor **2930**, and the encoder **2940**. The video encoding apparatus **2900** may include a memory controller (not illustrated) that manages data input and output of the data storages (not illustrated).

In order to output a result of video encoding, the video encoding apparatus **2900** may operate in connection with an internal video encoding processor or an external video encoding processor, so as to perform the video encoding operation including prediction. The internal video encoding processor of the video encoding apparatus **2900** may be an independent processor for performing a video encoding operation. Also, the video encoding apparatus **2900**, the central processor, or a graphic processor may include a video encoding processing module to perform a basic video encoding operation.

The video encoding apparatus **2900** may be included in the video encoding apparatus **100** of FIG. **1**. Specifically, the splitter **2910** may be included in the largest coding unit splitter **110** and the coding unit determiner **120**, the candidate selector **2920** and the predictor **2930** may be included in the intra predictor **420**, and the encoder **2940** may be included in the transformer **425**, the quantizer **430**, and the entropy encoder **435**. Therefore, the descriptions provided above with reference to FIGS. **1** and **4** will be omitted.

The splitter **2910** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded.

The type of the block may be a square, a rectangle, or any geometric shape. The block is not limited to a data unit having a constant size.

The candidate selector **2920** selects at least one adjacent sample adjacent to the current sample in the current block. Also, the candidate selector **2920** may select a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample of the current sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block.

The predictor **2930** obtains a prediction value of the current sample by using the first candidate sample selected by the candidate selector **2920**. Specifically, the predictor **2930** may obtain the prediction value of the current sample by using a reconstruction value of the first candidate sample included in the previous block reconstructed earlier than the current block.

The encoder **2940** encodes a residual value of the current sample. Specifically, the encoder **2940** may obtain a residual value between an original value of the current sample and a prediction value of the current sample obtained by the predictor **2930**, transform the residual value of the current sample, perform entropy encoding on the transformed residual value, and output the entropy-encoded residual value in a bitstream.

FIG. **30** illustrates a block diagram of a video decoding apparatus that can perform sample-wise prediction based on an already reconstructed sample.

A video decoding apparatus **3000** may include a splitter **3010**, a candidate selector **3020**, a predictor **3030**, and a decoder **3040**. The video decoding apparatus **3000** may include a central processor (not illustrated) that collectively controls the splitter **3010**, the candidate selector **3020**, the predictor **3030**, and the decoder **3040**. Alternatively, the splitter **3010**, the candidate selector **3020**, the predictor **3030**, and the decoder **3040** may be driven by their individual processors (not illustrated) that interoperate with one another to collectively control the video decoding apparatus **3000**. Alternatively, the splitter **3010**, the candidate selector

3020, the predictor 3030, and the decoder 3040 may be controlled under control of an external processor (not illustrated) disposed outside the video decoding apparatus 3000.

The video decoding apparatus 3000 may include one or more data storages (not illustrated) that store input and output data of the splitter 3010, the candidate selector 3020, the predictor 3030, and the decoder 3040. The video decoding apparatus 3000 may include a memory controller (not illustrated) that manages data input and output of the data storages (not illustrated).

In order to output a result of video decoding, the video decoding apparatus 3000 may operate in connection with an internal video encoding processor or an external video encoding processor, so as to perform the video decoding operation including prediction. The internal video decoding processor of the video decoding apparatus 3000 may be an independent processor for performing a video decoding operation. Also, the video decoding apparatus 3000, the central processor, or a graphic processor may include a video decoding processing module to perform a basic video decoding operation.

The video decoding apparatus 3000 may be included in the video decoding apparatus 200 of FIG. 2. Specifically, the splitter 3010 may be included in the receiver 210, and the predictor 3030, the candidate selector 3020, and the decoder 3040 may be included in the image data decoder 230. Therefore, the descriptions provided above with reference to FIG. 2 will be omitted.

The splitter 3010 splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded.

The type of the block may be a square, a rectangle, or any geometric shape. The block is not limited to a data unit having a constant size.

The candidate selector 3020 selects at least one adjacent sample adjacent to the current sample in the current block. Also, the candidate selector 3020 may select a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample of the current sample, from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block.

The predictor 3030 obtains a prediction value of the current sample by using the first candidate sample selected by the candidate selector 3020. Specifically, the predictor 3030 may obtain the prediction value of the current sample by using a reconstruction value of the first candidate sample included in the previous block reconstructed earlier than the current block.

The decoder 3040 decodes an image. Specifically, the decoder 3040 may reconstruct the image by using the residual value of the current sample obtained from the bitstream and the prediction value of the current sample obtained by the predictor 3030.

FIG. 31 illustrates an operation of sample-wise prediction to predict a current sample based on an already reconstructed sample.

The candidate selectors 2920 and 3020 may select at least one adjacent sample A predicted earlier than a current sample C in a current block 3100 split from an image and being adjacent to the current sample C.

At least one adjacent sample used for predicting the current sample C from among samples adjacent to the current sample C may change according to a prediction direction of the current block 3100. For example, when horizontal prediction 3110 is sequentially performed from an uppermost row (i=0) to a lowermost row (i=7) in the current block 3100 having a size of 8×8, a left adjacent sample A of the current sample C from among the adjacent samples of the current sample C may be selected as the sample for selecting the current sample C.

The candidate selectors 2920 and 3020 may select a first candidate sample C1 adjacent to a candidate adjacent sample C1A having a closest value to the adjacent sample A, from among candidate samples C1, C2, and C3 included in at least one previous block 3120, 3130, and 3140 reconstructed earlier than the current block 3100.

In the encoding apparatus 2900, the candidate samples C1, C2, and C3 of the current sample C may include all samples included in at least one previous block 3120, 3130, and 3140 reconstructed earlier than the current block 3100. Also, in the encoding apparatus 2900, the candidate samples C1, C2, and C3 of the current sample C may include samples located within a predetermined distance from the current sample C from among samples included in at least one previous block 3120, 3130, and 3140 reconstructed earlier than the current block 3100. The distance may be set based on a size of the current block 3100 and a position of the current block 3100 in the image. For example, as the size of the current block 3100 increases, the distance may increase. As the decoding order of the current block 3100 in the image is later than other blocks, the distance may increase.

The candidate selector 2920 of the encoding apparatus 2900 may select the first candidate sample C1 from among the candidate samples C1, C2, and C3, based on costs between the candidate samples C1, C2, and C3 and the current sample C. Specifically, the candidate selector 2920 of the encoding apparatus 2900 may calculate costs between the candidate samples C1, C2, and C3 and the current sample C and select the first candidate sample C1 having the minimum cost with respect to the current sample C from among the candidate samples C1, C2, and C3. The costs between one candidate sample (one of the candidate samples C1, C2, and C3) and the current sample C may denote a numerical index of dissimilarity between the candidate sample and the current sample. Therefore, the predictor 2930 of the encoding apparatus 2900 may predict the current sample C by using the first candidate sample C1 that has the lowest cost with respect to the current sample and is most similar to the current sample C from among the candidate samples C1, C2, and C3.

For example, the cost between the first candidate sample C1 and the current sample C may be obtained based on a difference between at least one candidate adjacent sample C1A adjacent to the first candidate sample C1 and at least one adjacent sample A adjacent to the current sample C. As the difference between the candidate adjacent sample C1A of the first candidate sample C1 and the adjacent sample A of the current sample C becomes smaller, the first candidate sample C1 may be similar to the current sample C. Thus, the cost between the first candidate sample C1 and the current sample C may decrease.

Also, the cost between the first candidate sample C1 and the current sample C may be corrected based on a distance between the current sample C and the first candidate sample C1, a direction in which the candidate adjacent sample C1A is adjacent to the candidate sample C1, and a direction in which the adjacent sample A is adjacent to the current sample C. Specifically, as the difference between the first candidate sample C1 and the current sample C becomes shorter, the first candidate sample C1 may be similar to the current sample C. Thus, the cost between the first candidate sample C1 and the current sample C may decrease. On the other hand, as the difference between the first candidate sample C1 and the current sample C becomes longer, the first candidate sample C1 may be dissimilar to the current sample C. Thus, the cost between the first candidate sample C1 and the current sample C may increase. Also, if the direction in which the candidate adjacent sample C1A is adjacent to the first candidate sample C1 matches the direction in which the adjacent sample A is adjacent to the current sample C, the first candidate sample C1 may be similar to the current sample C. Thus, the cost between the first candidate sample C1 and the current sample C may decrease. On the other hand, if the direction in which the candidate adjacent sample C1A is adjacent to the first candidate sample C1 does not match the direction in which the adjacent sample A is adjacent to the current sample C, the first candidate sample C1 may be dissimilar to the current sample C. Thus, the cost between the first candidate sample C1 and the current sample C may increase.

For example, the cost between one candidate sample and the current sample may be obtained based on Equation 6 below:

$$\text{Cost}-w_1\times\|p\text{TemplateCand}[y]-p\text{Teplate}[x]\|+w4\cdot\text{distance}^2+\text{orientation penalty};$$

$$\text{Minimum Cost}\rightarrow\text{Pred}[i_p,j_p]=\text{Candidate}[i_c,j_c];$$

$$\|p\text{TemplateCand}[y]-p\text{Template}[x]\|=\text{abs}(p\text{TemplateCand}[y]-p\text{Template}[x])$$

$$\text{distance}^2=(i_p-i_c)^2+(j_p-j_c)^2 \quad \text{[Equation 6]}$$

In Equation 6, pTemplateCand[y] may denote a candidate adjacent sample adjacent to a candidate sample Candidate [ic, jc] located at an ic^{th} row and a jc^{th} column in the image. Like the candidate sample, the candidate adjacent sample may be included in at least one previous block **3120**, **3130**, and **3140** decoded earlier than the current block **3100**. An index y of the candidate adjacent sample pTemplateCand[y] may denote a direction in which the candidate adjacent sample is adjacent to the candidate sample. For example, when y=1, the candidate adjacent sample may be adjacent to a left side of the candidate sample, when y=2, the candidate adjacent sample may be adjacent to an upper side of the candidate sample, and when y=3, the candidate adjacent sample may be adjacent to a left upper side of the candidate sample. For example, as illustrated in FIG. **31**, a y index of a left candidate adjacent sample C**1**A of a C**1** candidate sample may be 1, a y index of an upper candidate adjacent sample C**2**A of a C**2** candidate sample may be 1, and a y index of a left upper candidate adjacent sample C**3**A of a C**3** candidate sample may be 2.

In Equation 6, pTemplate[x] may denote a candidate sample adjacent to a current sample Pred[ip, jp] located at an ip^{th} row and a jp^{th} column in an image. An index x of an adjacent sample pTemplate[x] may denote a direction in which the adjacent sample is adjacent to the current sample. For example, when x=1, the adjacent sample may be adjacent to a left side of the current sample, when x=2, the adjacent sample may be adjacent to an upper side of the current sample, and when x=3, the adjacent sample may be adjacent to a left upper side of the current sample. For example, as illustrated in FIG. **31**, an x index of a left adjacent sample A of the current sample C may be 1.

In order to reduce a computation amount of the decoding apparatus **3000**, the encoding apparatus **2900** may transmit information about the candidate sample to the decoding apparatus **3000**.

For example, the encoding apparatus **2900** may encode information indicating the first candidate sample C**1** having the minimum cost with respect to the current sample C from among the samples included in at least one previous block **3120**, **3130**, and **3140** and transmit the encoded information to the decoding apparatus **3000**. When the encoding apparatus **2900** transmits the information indicating the first candidate sample C**1** to the decoding apparatus **3000**, the candidate selector **3020** of the decoding apparatus **3000** may select the first candidate sample C**1** from among the candidate samples C**1**, C**2**, and C**3** based on the received information, without calculating the costs of the candidate samples C**1**, C**2**, and C**3** with respect to the current sample C. Also, the predictor **3030** of the decoding apparatus **3000** may obtain a prediction value of the current sample C by using a reconstruction value of the first candidate sample C**1**.

In another example, the encoding apparatus **2900** may encode a candidate sample list indicating the candidate samples C**1**, C**2**, and C**3** having costs equal to or less than a threshold value with respect to the current sample C from among the samples included in at least one previous block **3120**, **3130**, and **3140** and transmit the encoded candidate sample list to the decoding apparatus **3000**. When the encoding apparatus **2900** transmits the candidate sample list to the decoding apparatus **3000**, the candidate selector **3020** of the decoding apparatus **3000** may select the first candidate sample from among the candidate samples C**1**, C**2**, and C**3** included in the candidate sample list. Specifically, the candidate selector **3020** of the decoding apparatus **3000** may select the first candidate sample C**1** having the minimum cost with respect to the current sample C from among the candidate samples C**1**, C**2**, and C**3** included in the candidate sample list. Also, the predictor **3030** of the decoding apparatus **3000** may predict the current sample C by using a reconstruction value of the selected first candidate sample C**1**.

In another example, the encoding apparatus **2900** may encode a predetermined distance for selecting the candidate samples C**1**, C**2**, and C**3** located within a predetermined distance from the current sample C from among the samples included in at least one previous block **3120**, **3130**, and **3140** and transmit the encoded predetermined distance to the decoding apparatus **3000**. When the encoding apparatus **2900** transmits the predetermined distance to the decoding apparatus **3000**, the candidate selector **3020** of the decoding apparatus **3000** may select the candidate samples C**1**, C**2**, and C**3** included in at least one previous block **3120**, **3130**, and **3140** based on the received predetermined distance. Also, the candidate selector **3020** of the decoding apparatus **3000** may select the first candidate sample C**1** having the minimum cost with respect to the current sample C from among the candidate samples C**1**, C**2**, and C**3** located within the predetermined distance from the current sample C. Also, the predictor **3030** of the decoding apparatus **3000** may predict the current sample C by using a reconstruction value of the selected first candidate sample C**1**.

When the predetermined distance for selecting the candidate samples C**1**, C**2**, and C**3** located within a predetermined distance from the current sample C from among the samples included in at least one previous block **3120**, **3130**, and **3140** is determined based on a size of the current block **3100**, the candidate selector **3020** of the decoding apparatus **3000** may select the candidate samples C**1**, C**2**, and C**3** based on size information of the current block **3100** or split information of the current block **3100** obtained from the bitstream. Specifically, the candidate selector **3020** of the decoding apparatus **3000** may obtain the predetermined distance based on the size information of the current block **3100** or the split information of the current block **3100** obtained from the bitstream. Also, the candidate selector **3020** of the decoding apparatus **3000** may select the first candidate sample C**1** having the minimum cost with respect to the current sample C from among the candidate samples C**1**, C**2**, and C**3** located within the predetermined distance from the current sample C. Also, the predictor **3030** of the decoding apparatus **3000** may predict the current sample C by using a reconstruction value of the selected first candidate sample C**1**.

If the current sample is predicted based on the sample already predicted in the same block, the encoding and decoding apparatuses and the encoding and decoding methods may perform adaptive prediction according to the position of the current sample, and encoding and decoding performance may be improved.

FIG. **32** illustrates adjacent samples available for predicting a current sample.

As described above, in order to select the first candidate sample from among the candidate samples, at least one adjacent sample may be selected from among the adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C. The adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C may include samples closest to the current sample C, such as the samples A**1** and A**4** adjacent to the current sample C in a horizontal direction and the samples A**2** and A**5** adjacent to the current sample C in a vertical direction. Also, the adjacent samples of the current sample C may include samples adjacent to the current sample C in a diagonal direction, such as the sample A**3** adjacent to a left upper side of the current sample C, the sample A**6** adjacent to a right lower side of the current sample C, the sample A**7** adjacent to a left lower side of the current sample C, and the sample A**8** adjacent to a right upper side of the current sample C.

The candidate selectors **2920** and **3020** may determine at least one sample for predicting the current sample C from among the adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C within the current block **3200** and reference samples **3250** of the current block **3200** outside the current block **3200**. For example, as illustrated in FIG. **32**, when the current sample C in the current block **3200** is not located at the boundary of the current block **3200** having a size of 4×4, the candidate selectors **2920** and **3020** may determine at least one adjacent sample for predicting the current sample C from among a left adjacent sample A**1**, an upper adjacent sample A**2**, a left upper adjacent sample A**3**, a right adjacent sample A**4**, a lower adjacent sample A**5**, a right lower adjacent sample A**6**, a left lower adjacent sample A**7**, and a right upper adjacent sample A**8**, which are located in the current block **3200**. In another example, when the current sample C is located at the boundary of the current block **3200** like the sample A**3**, the candidate selectors **2920** and **3020** may determine at least one adjacent sample for predicting the current sample C from among the reference samples **3250** of the current block **3200**. The candidate selectors **2920** and **3020** may determine at least one adjacent sample for predicting the current sample C from among the adjacent samples A**1**, A**2**, A**3**, A**4**, A**5**, A**6**, A**7**, and A**8** of the current sample C based on the prediction order in the current block **3200**. Since the current sample c can be predicted by using the sample whose prediction order is ahead of the prediction order of the current sample C, the adjacent sample available for predicting the current sample may change according to the prediction order in the current block.

For example, when horizontal prediction **3210** is sequentially performed from an uppermost row (i=0) to a lowermost row (i=3) in the current block **3200** having a size of 4×4, at least one of the left adjacent sample A**1**, the upper adjacent sample A**2**, the left upper adjacent sample A**3**, and the right upper adjacent sample A**8** of the current sample C may be used to predict the current sample C.

In another example, when vertical prediction **3220** is sequentially performed from a leftmost column (j=0) to a rightmost column (j=3) in the current block **3200** having a size of 4×4, at least one of the left adjacent sample A**1**, the upper adjacent sample A**2**, the left upper adjacent sample A**3**, and the left lower adjacent sample A**7** of the current sample C may be used to predict the current sample C.

In another example, when left lower diagonal prediction **1930** is sequentially performed from a leftmost upper sample A**3** to a rightmost lower sample E in the current block **3230** having a size of 4×4, at least one of the left adjacent sample A**1**, the upper adjacent sample A**2**, the left upper adjacent sample A**3**, and the right upper adjacent sample A**8** of the current sample C may be used to predict the current sample C.

In another example, when right upper diagonal prediction **1930** is sequentially performed from a rightmost lower sample S to a leftmost upper sample A**3** in the current block **3240** having a size of 4×4, at least one of the right adjacent sample A**4**, the lower adjacent sample A**5**, the right lower adjacent sample **63**, and the left lower adjacent sample A**7** of the current sample C may be used to predict the current sample C.

The prediction direction of the current block **3200** is not limited to the horizontal prediction **1910**, the vertical prediction **1920**, the left lower diagonal prediction **1930**, and the right upper diagonal prediction **1940** of FIG. **19**. The samples used to predict the current sample C may change based on the position of the current sample C in the current block **3200** and the prediction direction of the current block **3200**.

FIG. **33** illustrates candidate samples located within a predetermined distance from a current sample.

The candidate selectors **2920** and **3020** may select candidate samples located within a certain distance d**1** from a current sample C from among samples included in at least one previous block **3310**, **3320**, and **3330** decoded earlier than the current block **3300** split from an image. For example, samples included in a circle **3340** having a radius corresponding to the certain distance d**1** around the current sample C may be candidate samples.

The certain distance d**1** for defining the candidate samples among from the samples in the image may be determined based on a size of the current block **3300** and decoding order of the current block **3300** in the image. For example, as the size of the current block **3300** increases, more candidate samples are required. Thus, the distance d**1** may increase. In another example, as the decoding order of the current block **3300** is later, samples that can be referred to increase. Thus, the distance d**1** may increase.

FIG. **34** illustrates an operation of correcting costs based on a distance between a current sample and a candidate sample.

The candidate selectors **2920** and **3020** may select a first candidate sample C**1** for predicting the current sample C from among candidate samples C**1**, C**2**, and C**3** based on a difference value between an adjacent sample A adjacent to the current sample C and each of candidate adjacent samples C**1**A, C**2**A, and C**3**A adjacent to the candidate samples C**1**, C**2**, and C**3**.

Specifically, the candidate selectors **2920** and **3020** may obtain costs between the candidate adjacent samples C**1**A, C**2**A, and C**3**A and the adjacent sample A and correct the costs based on a distance between the candidate samples C**1**, C**2**, and C**3** and the current sample C. The candidate selectors **2920** and **3020** may select the first candidate sample C**1** having a corrected minimum cost from among the candidate samples C**1**, C**2**, and C**3**.

For example, as the distance between the candidate samples C**1**, C**2**, and C**3** and the current sample C decreases, the cost between the candidate sample (one of the candidate samples C**1**, C**2**, and C**3**) and the current sample C may decrease. On the other hand, as the distance between the candidate sample (one of the candidate samples C**1**, C**2**, and C**3**) and the current sample C increases, the cost between the candidate sample (one of the candidate samples C**1**, C**2**, and C**3**) and the current sample C may increase.

As illustrated in FIG. **31**, when a distance dc**3** between the current sample C and the third candidate sample C**3** is longer than a distance dc**1** between the current sample C and the first candidate sample C**1** and shorter than a distance dc**2** between the current sample C and the second candidate sample C**2**, an increasing amount of the cost between the current sample C and the candidate sample C**3** may be larger than an increasing amount of the cost between the current sample C**1** and the candidate sample C**1** and smaller than an increasing amount of the cost between the current sample C and the candidate sample C**2**.

FIG. **35** illustrates an operation of correcting costs based on a direction in which a candidate adjacent sample is adjacent to a candidate sample.

The candidate selectors **2920** and **3020** may select a first candidate sample C**1** for predicting the current sample C from among candidate samples C**1**, C**2**, and C**3** based on a difference value between an adjacent sample A adjacent to the current sample and each of candidate adjacent samples adjacent to candidate samples C**1**, C**2**, and C**3**, a direction in which the current sample C is adjacent to the adjacent sample A, and a direction in which the candidate samples C**1**, C**2**, and C**3** are adjacent to the candidate adjacent samples C**1**A, C**2**A, and C**3**A.

Specifically, the candidate selectors **2920** and **3020** may obtain costs between the candidate adjacent samples C**1**A, C**2**A, and C**3**A and the adjacent sample A and correct the costs based on the direction in which the candidate adjacent samples C**1**A, C**2**A, and C**3**A are adjacent to the candidate samples C**1**, C**2**, and C**3** and the direction in which the adjacent sample A is adjacent to the current sample C.

For example, if the direction in which the candidate adjacent sample C**1**A is adjacent to the candidate sample C**1** matches the direction in which the adjacent sample A is adjacent to the current sample C, the cost between the first candidate sample C**1** and the current sample C may decrease by alpha. On the other hand, if the direction in which the candidate adjacent samples C**2**A and C**3**A is adjacent to the candidate samples C**2** and C**3** matches the direction in which the adjacent sample A is adjacent to the current sample C, the cost between the candidate samples C**2** and C**3** and the current sample C may increase by alpha.

FIG. **36** illustrates an operation of sample-wise prediction to predict a current sample based on a plurality of already reconstructed samples.

The candidate selectors **2920** and **3020** may select a plurality of adjacent samples A**1** and A**2** predicted earlier than a current sample C in a current block **3600** split from an image and being adjacent to the current sample C.

The candidate selectors **2920** and **3020** may select a first candidate sample C**1** adjacent to a plurality of candidate adjacent samples C**1**A**1** and C**1**A**2** having a closest value to a plurality of adjacent samples A**1** and A**2**, from among candidate samples C**1**, C**2**, and C**3** included in at least one previous block **3620**, **3630**, and **3640** reconstructed earlier than the current block **3600**.

The candidate selector **2920** of the encoding apparatus **2900** may select the first candidate sample C**1** from among the candidate samples C**1**, C**2**, and C**3**, based on costs between the candidate samples C**1**, C**2**, and C**3** and the current sample C. Specifically, the candidate selector **2920** of the encoding apparatus **2900** may calculate costs between the candidate samples C**1**, C**2**, and C**3** and the current sample C and select the first candidate sample C**1** having a minimum cost with respect to the current sample C from among the candidate samples C**1**, C**2**, and C**3**. For example, the cost between one candidate sample and the current sample may be obtained based on Equation 7 below:

$$\mathrm{Cost}=w_1\times\|p\mathrm{TemplateCand}[y1]-p\mathrm{Template}[x1]\|+w_2\times\|p\mathrm{TemplateCand}[y2]-p\mathrm{Template}[x2]\|+w4\cdot\mathrm{distance}^2+\mathrm{orientation\ penalty};$$

$$\mathrm{MinimumCost}\rightarrow\mathrm{Pred}[i_p,j_p]=\mathrm{Candidate}[i_c,j_c];$$

$$\|p\mathrm{TemplateCand}[y]-p\mathrm{Template}[x]\|=\mathrm{abs}(p\mathrm{TemplateCand}[y]-p\mathrm{Template}[x])$$

$$\mathrm{distance}^2=(i_p-i_c)^2+(j_p-j_c)^2 \qquad \text{[Equation 7]}$$

Specifically, the candidate selectors **2920** and **3020** may obtain the cost between the current sample C and the C**1** candidate sample by using a value obtained by applying a weight w**1** to a difference between the C**1**A**1** candidate adjacent sample and the A**1** adjacent sample and a value obtained by applying a weight w**2** to a difference between the C**1**A**2** candidate adjacent sample and the A**2** adjacent sample. The candidate selectors **2920** and **3020** may correct the cost between the C**1** candidate sample and the current sample C based on a distance between the C**1** candidate sample and the current sample C. The candidate selectors **2920** and **3020** may correct the cost between the C**1** candidate sample and the current sample C based on a direction in which the C**1**A**1** candidate adjacent sample is adjacent to the C**1** candidate sample, a direction in which the C**1**A**2** candidate adjacent sample is adjacent to the C**1** candidate sample, a direction in which the A**1** adjacent sample is adjacent to the current sample C, and a direction in which the A**2** adjacent sample is adjacent to the current sample C.

The candidate selectors **2920** and **3020** may obtain the cost between the current sample C and the C**2** candidate sample by using a value obtained by applying a weight w**1** to a difference between the C**2**A**4** candidate adjacent sample and the A**1** adjacent sample and a value obtained by applying a weight w**2** to a difference between the C**2**A**5** candidate adjacent sample and the A**2** adjacent sample. The candidate selectors **2920** and **3020** may correct the cost between the C**2** candidate sample and the current sample C based on a distance between the C**2** candidate sample and the current sample C. The candidate selectors **2920** and **3020** may correct the cost between the C**2** candidate sample and the current sample C based on a direction in which the C**2**A**4** candidate adjacent sample is adjacent to the C**2** candidate sample, a direction in which the C**2**A**5** candidate adjacent sample is adjacent to the C**2** candidate sample, a direction in which the A**1** adjacent sample is adjacent to the current sample C, and a direction in which the A**2** adjacent sample is adjacent to the current sample C.

The candidate selectors **2920** and **3020** may obtain the cost between the current sample C and the C**3** candidate sample by using a value obtained by applying a weight w**1** to a difference between the C**3**A**1** candidate adjacent sample and the A**1** adjacent sample and a value obtained by applying a weight w**2** to a difference between the C**3**A**3** candidate adjacent sample and the A**2** adjacent sample. The candidate selectors **2920** and **3020** may correct the cost between the C**3** candidate sample and the current sample C based on a distance between the C**3** candidate sample and the current sample C. The candidate selectors **2920** and **3020** may correct the cost between the C**3** candidate sample and the current sample C based on a direction in which the C**3**A**1** candidate adjacent sample is adjacent to the C**3** candidate sample, a direction in which the C**3**A**3** candidate adjacent sample is adjacent to the C**3** candidate sample, a direction in which the A**1** adjacent sample is adjacent to the current sample C, and a direction in which the A**2** adjacent sample is adjacent to the current sample C.

As described above with reference to FIG. **21**, the weight w**1** for the A**1** adjacent sample adjacent to the current sample in the horizontal direction may be proportional to the vertical gradient of the current block **3600**. As described above with reference to FIG. **21**, the weight w**1** for the left adjacent sample A of the current sample may be proportional to the vertical gradient of the current block **3600**. Also, as described above with reference to FIG. **22**, the weight w**2** for the A**2** adjacent sample adjacent to the current sample in the vertical direction may be proportional to the horizontal gradient of the current block **3600**. Also, the weight w**1** and the weight w**2** may be preset to have the same value.

The candidate selectors **2920** and **3020** may select the first candidate sample C**1** having a minimum cost with respect to the current sample from among the candidate samples C**1**, C**2**, and C**3** and obtain a prediction value of the current sample C by using a reconstruction value of the first candidate sample C**1**.

FIG. **37** illustrates an operation of correcting costs based on a direction in which a plurality of candidate adjacent samples are adjacent to a candidate sample.

The candidate selectors **2920** and **3020** may correct the cost between the C**1** candidate sample and the current sample C based on a direction in which the C**1**A**1** candidate adjacent sample and the C**1**A**2** candidate adjacent sample are adjacent to the C**1** candidate sample and a direction in which the A**1** adjacent sample and the A**2** adjacent sample are adjacent to the current sample C.

The candidate selectors **2920** and **3020** may correct the cost between the C**2** candidate sample and the current sample C based on a direction in which the C**2**A**4** candidate adjacent sample and the C**2**A**5** candidate adjacent sample are adjacent to the C**2** candidate sample and a direction in which the A**1** adjacent sample and the A**2** adjacent sample are adjacent to the current sample C.

The candidate selectors **2920** and **3020** may correct the cost between the C**3** candidate sample and the current sample C based on a direction in which the C**3**A**1** candidate adjacent sample and the C**3**A**3** candidate adjacent sample are adjacent to the C**3** candidate sample and a direction in which the A**1** adjacent sample and the A**2** adjacent sample are adjacent to the current sample C.

For example, the cost corrected based on a direction in which n candidate adjacent samples are adjacent to the candidate sample may be in a range of −n*alpha to +n*alpha. Specifically, if the directions in which the n candidate adjacent samples are adjacent to the candidate sample match a direction in which the adjacent samples are adjacent to the current sample, a correction value of the cost may be −n*alpha. On the other hand, if the directions in which the n candidate adjacent samples are adjacent to the candidate sample do not match a direction in which the adjacent samples are adjacent to the current sample, a correction value of the cost may be +n*alpha.

For example, since the directions in which the C**1**A**2** candidate adjacent sample and the C**1**A**2** candidate adjacent sample are adjacent to the C**1** candidate sample match the direction in which the A**1** adjacent sample and the A**2** adjacent sample are adjacent to the current sample C, a correction value of the cost between the C**1** candidate sample and the current sample C may be −2*alpha.

Also, since the directions in which the C**2**A**4** candidate adjacent sample and the C**2**A**5** candidate adjacent sample are adjacent to the C**2** candidate sample match the direction in which the A**1** adjacent sample and the A**2** adjacent sample are adjacent to the current sample C, a correction value of the cost between the C**2** candidate sample and the current sample C may be +2*alpha.

Also, since the direction in which the C**3**A**1** candidate adjacent sample is adjacent to the C**3** candidate sample matches the direction in which the A**1** adjacent sample is adjacent to the current sample C but the direction in which the C**3**A**3** candidate adjacent sample is adjacent to the C**3** candidate sample does not match the direction in which the A**2** adjacent sample is adjacent to the current sample C, a correction value of the cost between the C**3** candidate sample and the current sample C may be alpha-alpha=0.

FIG. **38** illustrates another operation of sample-wise prediction to predict a current sample based on a plurality of already reconstructed samples.

The candidate selectors **2920** and **3020** may select a plurality of adjacent samples A**1**, A**2**, and A**3** predicted earlier than a current sample C in a current block **3800** split from an image and being adjacent to the current sample C.

The candidate selectors **2920** and **3020** may select a first candidate sample C**1** adjacent to a plurality of candidate adjacent samples C**1**A**1**, C**1**A**2**, and C**1**A**3** having a closest value to a plurality of adjacent samples A**1**, A**2**, and A**3**, from among candidate samples C**1**, C**2**, and C**3** included in at least one previous block **3820**, **3830**, and **3840** reconstructed earlier than the current block **3800**.

The candidate selector **2920** of the encoding apparatus **2900** may select the first candidate sample C**1** from among the candidate samples C**1**, C**2**, and C**3**, based on costs between the candidate samples C**1**, C**2**, and C**3** and the current sample C. Specifically, the candidate selector **2920** of the encoding apparatus **2900** may calculate costs between the candidate samples C**1**, C**2**, and C**3** and the current sample C and select the first candidate sample C**1** having a minimum cost with respect to the current sample C from among the candidate samples C**1**, C**2**, and C**3**. For example, the cost between one candidate sample and the current sample may be obtained based on Equation 8 below:

$$\text{Cost}=w_1\times\|p\text{TemplateCand}[y1]-p\text{Template}[x1]\|+w_2\times\|p\text{TemplateCand}[y2]-p\text{Template}[x2]\|+w_3\times\|p\text{TemplateCand}[y3]-p\text{Template}[x3]\|+w4\cdot\text{distance}^2+\text{orientation penalty};$$

$$\text{Minimum Cost}\rightarrow\text{Pred}[i_p,j_p]=\text{Candidate}[i_c,j_c];$$

$$\|p\text{TemplateCand}[y]-p\text{Template}[x]\|=\text{abs}(p\text{TemplateCand}[y]-p\text{Template}[x])$$

$$\text{distance}=(i_p-i_c)^2+(j_p-j_c)^2 \qquad \text{[Equation 8]}$$

Specifically, the candidate selectors **2920** and **3020** may obtain the cost between the current sample C and the C**1** candidate sample by using a value obtained by applying a weight w**1** to a difference between the C**1**A**1** candidate adjacent sample and the A**1** adjacent sample, a value obtained by applying a weight w**2** to a difference between the C**1**A**2** candidate adjacent sample and the A**2** adjacent sample, and a value obtained by applying a weight w**3** to a difference between the C**1**A**3** candidate adjacent sample and the A**3** adjacent sample. The candidate selectors **2920** and **3020** may correct the cost between the C**1** candidate sample and the current sample C based on a distance between the C**1** candidate sample and the current sample C. The candidate selectors **2920** and **3020** may correct the cost between the C**1** candidate sample and the current sample C based on a direction in which the C**1**A**1** candidate adjacent sample is adjacent to the C**1** candidate sample, a direction in which the C**1**A**2** candidate adjacent sample, the C**1**A**2** candidate adjacent sample, and the C**1**A**3** candidate adjacent sample are adjacent to the C**1** candidate sample, and a direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C.

The candidate selectors **2920** and **3020** may obtain the cost between the current sample C and the C**2** candidate sample by using a value obtained by applying a weight w**1** to a difference between the C**2**A**4** candidate adjacent sample and the A**1** adjacent sample, a value obtained by applying a weight w**2** to a difference between the C**2**A**5** candidate adjacent sample and the A**2** adjacent sample, and a value obtained by applying a weight w**3** to a difference between the C**2**A**6** candidate adjacent sample and the A**3** adjacent sample. The candidate selectors **2920** and **3020** may correct the cost between the C**2** candidate sample and the current sample C based on a distance between the C**2** candidate sample and the current sample C. The candidate selectors **2920** and **3020** may correct the cost between the C**2** candidate sample and the current sample C based on a direction in which the C**2**A**4** candidate adjacent sample, the C**2**A**5** candidate adjacent sample, and the C**2**A**6** candidate adjacent sample are adjacent to the C**2** candidate sample and a direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C.

The candidate selectors **2920** and **3020** may obtain the cost between the current sample C and the C**3** candidate sample by using a value obtained by applying a weight w**1** to a difference between the C**3**A**4** candidate adjacent sample and the A**1** adjacent sample, a value obtained by applying a weight w**2** to a difference between the C**3**A**2** candidate adjacent sample and the A**2** adjacent sample, and a value obtained by applying a weight w**3** to a difference between the C**3**A**8** candidate adjacent sample and the A**3** adjacent sample. The candidate selectors **2920** and **3020** may correct the cost between the C**3** candidate sample and the current sample C based on a distance between the C**3** candidate sample and the current sample C. The candidate selectors **2920** and **3020** may correct the cost between the C**3** candidate sample and the current sample C based on a direction in which the C**3**A**2** candidate adjacent sample, the C**3**A**4** candidate adjacent sample, and the C**3**A**8** candidate adjacent sample are adjacent to the C**3** candidate sample and a direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C.

As described above with reference to FIG. **21**, the weight w**1** for the A**1** adjacent sample adjacent to the current sample in the horizontal direction may be proportional to the vertical gradient of the current block **3800**. As described above with reference to FIG. **21**, the weight w**1** for the left adjacent sample A of the current sample may be proportional to the vertical gradient of the current block **3800**. Also, as described above with reference to FIG. **22**, the weight w**2** for the A**2** adjacent sample adjacent to the current sample in the vertical direction may be proportional to the horizontal gradient of the current block **3800**. Also, the weight w**1** and the weight w**2** may be preset to have the same value. Also, the weight w**3** may be set based on the weight w**1** and the weight w**2**.

The candidate selectors **2920** and **3020** may select the first candidate sample C**1** having a minimum cost with respect to the current sample from among the candidate samples C**1**, C**2**, and C**3** and obtain a prediction value of the current sample C by using a reconstruction value of the first candidate sample C**1**.

FIG. **39** illustrates an operation of correcting costs based on a direction in which a plurality of candidate adjacent samples are adjacent to a candidate sample.

The candidate selectors **2920** and **3020** may correct the cost between the C**1** candidate sample and the current sample C based on a direction in which the C**1**A**1** candidate adjacent sample, the C**1**A**2** candidate adjacent sample, and the C**1**A**3** candidate adjacent sample are adjacent to the C**1** candidate sample and a direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C.

The candidate selectors **2920** and **3020** may correct the cost between the C**2** candidate sample and the current sample C based on a direction in which the C**2**A**4** candidate adjacent sample, the C**2**A**5** candidate adjacent sample, and the C**2**A**6** candidate adjacent sample are adjacent to the C**2** candidate sample and a direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C.

The candidate selectors **2920** and **3020** may correct the cost between the C**3** candidate sample and the current sample C based on a direction in which the C**3**A**2** candidate adjacent sample, the C**3**A**4** candidate adjacent sample, and the C**3**A**8** candidate adjacent sample are adjacent to the C**3** candidate sample and a direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C.

For example, the cost corrected based on a direction in which n candidate adjacent samples are adjacent to the candidate sample may be in a range of −n*alpha to +n*alpha. Specifically, if a direction in which the n candidate adjacent samples are adjacent to the candidate sample matches a direction in which the current samples are adjacent to the current sample, the corrected cost may be −n*alpha. On the other hand, if the directions in which the n candidate adjacent samples are adjacent to the candidate sample do not match a direction in which the adjacent samples are adjacent to the current sample, a correction value of the cost may be +n*alpha.

For example, since the directions in which the C**1**A**1** candidate adjacent sample, the C**1**A**2** candidate adjacent sample, and the C**1**A**3** candidate adjacent sample are adjacent to the C**1** candidate sample match the direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C, a correction value of the cost between the C**1** candidate sample and the current sample C may be −3*alpha.

Also, since the directions in which the C**2**A**4** candidate adjacent sample, the C**2**A**5** candidate adjacent sample, and the C**2**A**6** candidate adjacent sample are adjacent to the C**2** candidate sample match the direction in which the A**1** adjacent sample, the A**2** adjacent sample, and the A**3** adjacent sample are adjacent to the current sample C, a correction value of the cost between the C**2** candidate sample and the current sample C may be +3*alpha.

Also, since the direction in which the C**3**A**2** candidate adjacent sample is adjacent to the C**3** candidate sample matches the direction in which the A**2** adjacent sample is adjacent to the current sample C but the directions in which the C**3**A**4** candidate adjacent sample and the C**3**A**8** candidate adjacent sample are adjacent to the C**3** candidate sample do not match the direction in which the A**1** adjacent sample and the A**3** adjacent sample are adjacent to the current sample C, a correction value of the cost between the C**3** candidate sample and the current sample C may be 2alpha−alpha=alpha.

FIG. **40** is a flowchart of a video encoding method that can perform sample-wise prediction based on an already reconstructed adjacent sample.

In operation **4010**, a video encoding method **4000** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded. Operation **4010** may be performed by the splitter **2910** of the video encoding apparatus **2900**.

In operation **4020**, the video encoding method **4000** selects at least one adjacent sample adjacent to a current sample in a current block. Also, the video encoding method **4000** may select a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample of the current sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block. Operation **4020** may be performed by the candidate selector **2920** of the video encoding apparatus **2900**.

In operation **4030**, the video encoding method **4000** obtains a prediction value of the current sample by using the first candidate sample selected in operation **4020**. Specifically, the video encoding method **4000** may obtain the prediction value of the current sample by using a reconstruction value of the first candidate sample included in the previous block reconstructed earlier than the current block. Operation **4030** may be performed by the predictor **2930** of the video encoding apparatus **2900**.

In operation **4040**, the video encoding method **4000** encodes a residual value of the current sample. Specifically, the video encoding method **4000** may obtain a residual value between an original value of the current sample and a prediction value of the current sample obtained in operation **4020**, transform the residual value of the current sample, perform entropy encoding on the transformed residual value, and output the entropy-encoded residual value in a bitstream. Operation **4040** may be performed by the encoder **2940** of the video encoding apparatus **2900**.

FIG. **41** is a flowchart of a video decoding method that can perform sample-wise prediction based on an already reconstructed adjacent sample.

In operation **4110**, a video decoding method **4100** splits an image into at least one block. The term 'block' may refer to a largest coding unit, a coding unit, a transformation unit, or a prediction unit, which is split from an image to be encoded or decoded. Operation **4110** may be performed by the splitter **3010** of the video decoding apparatus **3000**.

In operation **4120**, the video decoding method **4100** selects at least one adjacent sample adjacent to a current sample in a current block. Also, the video decoding method **4100** may select a first candidate sample adjacent to a candidate adjacent sample having a closest value to the adjacent sample of the current sample from among a plurality of candidate samples included in at least one previous block reconstructed earlier than the current block. Operation **4120** may be performed by the candidate selector **3020** of the video decoding apparatus **3000**.

In operation **4130**, the video decoding method **4100** obtains a prediction value of the current sample by using the first candidate sample selected in operation **4120**. Specifically, the video decoding method **4100** may obtain the prediction value of the current sample by using a reconstruction value of the first candidate sample included in the previous block reconstructed earlier than the current block. Operation **4130** may be performed by the predictor **3030** of the video decoding apparatus **3000**.

In operation **4140**, the video decoding method **4100** encodes a residual value of the current sample. Specifically, the video decoding method **4100** may reconstruct the image by using the residual value of the current sample obtained from the bitstream and the prediction value of the current sample obtained by the predictor **3030**. Operation **4140** may be performed by the encoder **3041** of the video decoding apparatus **3000**.

The encoding and decoding apparatuses and the encoding and decoding methods, which can perform sample-wise prediction described above with reference to FIGS. **16** through **41**, may perform adaptive prediction according to the position of the current sample, and encoding and decoding performance may be improved.

The one or more embodiments may be written as computer programs and may be implemented in general-use digital computers that execute the programs by using a non-transitory computer-readable recording medium. Examples of the computer-readable recording medium include magnetic storage media (e.g., ROM, floppy disks, hard disks, etc.), optical recording media (e.g., CD-ROMs, or DVDs), etc.

For convenience of description, the image encoding methods and/or the video encoding method, which are described with reference to FIGS. **1** through **41**, will be collectively referred to as 'the video encoding method'. Also, the image decoding methods and/or the video decoding method, which are described with reference to FIGS. **1** through **41**, will be collectively referred to as 'the video decoding method'.

A non-transitory computer-readable recording medium such as a disc **26000** that stores the programs according to an embodiment will now be described in detail.

FIG. **42** illustrates a physical structure of the disc **26000** in which a program is stored, according to various embodiments. The disc **26000**, which is a storage medium, may be a hard drive, a compact disc-read only memory (CD-ROM) disc, a Blu-ray disc, or a digital versatile disc (DVD). The disc **26000** includes a plurality of concentric tracks Tr that are each divided into a specific number of sectors Se in a circumferential direction of the disc **26000**. In a specific region of the disc **26000**, a program that executes the quantized parameter determining method, the video encoding method, and the video decoding method described above may be assigned and stored.

A computer system embodied using a storage medium that stores a program for executing the video encoding method and the video decoding method as described above will now be described with reference to FIG. **44**.

FIG. **43** illustrates a disc drive **26800** for recording and reading a program by using the disc **26000**. A computer system **26700** may store a program that executes at least one of the video encoding method and the video decoding method according to an embodiment, in the disc **26000** via the disc drive **26800**. In order to run the program stored in the disc **26000** in the computer system **26700**, the program may be read from the disc **26000** and be transmitted to the computer system **26700** by using the disc drive **26800**.

The program that executes at least one of the video encoding method and the video decoding method according to an embodiment may be stored not only in the disc **26000** illustrated in FIGS. **42** and **43** but may also be stored in a memory card, a ROM cassette, or a solid state drive (SSD).

A system to which the video encoding method and the video decoding method described above are applied will be described below.

FIG. **44** illustrates an overall structure of a content supply system **11000** for providing a content distribution service. A service area of a communication system is divided into predetermined-sized cells, and wireless base stations **11700**, **11800**, **11900**, and **12000** are installed in these cells, respectively.

The content supply system **11000** includes a plurality of independent devices. For example, the plurality of independent devices, such as a computer **12100**, a personal digital assistant (PDA) **12200**, a video camera **12300**, and a mobile phone **12500**, are connected to the Internet **11100** via an internet service provider **11200**, a communication network **11400**, and the wireless base stations **11700**, **11800**, **11900**, and **12000**.

However, the content supply system **11000** is not limited to the structure as illustrated in FIG. **46**, and devices may be selectively connected thereto. The plurality of independent devices may be directly connected to the communication network **11400**, not via the wireless base stations **11700**, **11800**, **11900**, and **12000**.

The video camera **12300** is an imaging device, e.g., a digital video camera, which is capable of capturing video images. The mobile phone **12500** may employ at least one communication method from among various protocols, e.g., Personal Digital Communications (PDC), Code Division Multiple Access (CDMA), Wideband-Code Division Multiple Access (W-CDMA), Global System for Mobile Communications (GSM), and Personal Handyphone System (PHS).

The video camera **12300** may be connected to a streaming server **11300** via the wireless base station **11800** and the communication network **11400**. The streaming server **11300** allows content received from a user via the video camera **12300** to be streamed via a real-time broadcast. The content received from the video camera **12300** may be encoded by the video camera **12300** or the streaming server **11300**. Video data captured by the video camera **12300** may be transmitted to the streaming server **11300** via the computer **12100**.

Video data captured by a camera **12600** may also be transmitted to the streaming server **11300** via the computer **12100**. The camera **12600** such as a digital camera is an imaging device capable of capturing both still images and video images. The video data captured by the camera **12600** may be encoded by using the camera **12600** or the computer **12100**. Software that performs encoding and decoding video may be stored in a computer-readable recording medium, e.g., a CD-ROM disc, a floppy disc, a hard disc drive, an SSD, or a memory card, which may be accessible by the computer **12100**.

If video data is captured by a camera built in the mobile phone **12500**, the video data may be received from the mobile phone **12500**.

The video data may also be encoded by a large scale integrated circuit (LSI) system installed in the video camera **12300**, the mobile phone **12500**, or the camera **12600**.

In the content supply system **11000** according to an embodiment, content data, e.g., content recorded during a concert, which has been recorded by a user using the video camera **12300**, the camera **12600**, the mobile phone **12500**, or another imaging device is encoded and is transmitted to the streaming server **11300**. The streaming server **11300** may transmit the encoded content data in a type of a streaming content to other clients that request the content data.

The clients are devices capable of decoding the encoded content data, e.g., the computer **12100**, the PDA **12200**, the video camera **12300**, or the mobile phone **12500**. Thus, the content supply system **11000** allows the clients to receive and reproduce the encoded content data. Also, the content supply system **11000** allows the clients to receive the encoded content data and decode and reproduce the encoded content data in real time, thereby enabling personal broadcasting.

Encoding and decoding operations of the plurality of independent devices included in the content supply system **11000** may be similar to those of the video encoding apparatus and the video decoding apparatus according to an embodiment.

With reference to FIGS. **45** and **46**, the mobile phone **12500** included in the content supply system **11000** according to an embodiment will now be described in detail.

FIG. **45** illustrates an external structure of the mobile phone **12500** to which the video encoding method and the video decoding method are applied, according to various embodiments. The mobile phone **12500** may be a smart phone, the functions of which are not limited and a large number of the functions of which may be changed or expanded.

The mobile phone **12500** includes an internal antenna **12510** via which a radio-frequency (RF) signal may be exchanged with the wireless base station **12000**, and includes a display screen **12420** for displaying images captured by a camera **12310** or images that are received via the antenna **12510** and decoded, e.g., a liquid crystal display (LCD) or an organic light-emitting diode (OLED) screen. The mobile phone **12500** includes an operation panel **12540** including a control button and a touch panel. If the display screen **12420** is a touch screen, the operation panel **12540** further includes a touch sensing panel of the display screen **12420**. The mobile phone **12500** includes a speaker **12580** for outputting voice and sound or another type of a sound output unit, and a microphone **12550** for inputting voice and sound or another type of a sound input unit. The mobile phone **12500** further includes the camera **12310**, such as a charge-coupled device (CCD) camera, to capture video and still images. The mobile phone **12500** may further include a storage medium **12570** for storing encoded/decoded data, e.g., video or still images captured by the camera **12310**, received via email, or obtained according to various ways; and a slot **12560** via which the storage medium **12570** is loaded into the mobile phone **12500**. The storage medium **12570** may be a flash memory, e.g., a secure digital (SD) card or an electrically erasable and programmable read only memory (EEPROM) included in a plastic case.

FIG. **46** illustrates an internal structure of the mobile phone **12500**. In order to systemically control parts of the mobile phone **12500** including the display screen **12420** and the operation panel **12540**, a power supply circuit **12700**, an operation input controller **12640**, an image encoder **12720**, a camera interface **12630**, an LCD controller **12620**, an image decoder **12690**, a multiplexer/demultiplexer **12680**, a recording/reading unit **12670**, a modulation/demodulation unit **12660**, and a sound processor **12650** are connected to a central controller **12710** via a synchronization bus **12730**.

If a user operates a power button and sets from a 'power off' state to a 'power on' state, the power supply circuit **12700** supplies power to all the parts of the mobile phone **12500** from a battery pack, thereby setting the mobile phone **12500** to an operation mode.

The central controller **12710** includes a central processing unit (CPU), a read-only memory (ROM), and a random access memory (RAM).

While the mobile phone **12500** transmits communication data to the outside, a digital signal is generated by the mobile phone **12500** under control of the central controller **12710**. For example, the sound processor **12650** may generate a digital sound signal, the image encoder **12720** may generate a digital image signal, and text data of a message may be generated via the operation panel **12540** and the operation input controller **12640**. When a digital signal is transmitted to the modulation/demodulation unit **12660** by control of the central controller **12710**, the modulation/demodulation unit **12660** modulates a frequency band of the digital signal, and a communication circuit **12610** performs digital-to-analog conversion (DAC) and frequency conversion on the frequency band-modulated digital sound signal. A transmission signal output from the communication circuit **12610** may be transmitted to a voice communication base station or the wireless base station **12000** via the antenna **12510**.

For example, when the mobile phone **12500** is in a conversation mode, a sound signal obtained via the microphone **12550** is converted to a digital sound signal by the sound processor **12650** by the control of the central controller **12710**. The generated digital sound signal may be converted to a transmission signal through the modulation/demodulation unit **12660** and the communication circuit **12610**, and may be transmitted via the antenna **12510**.

When a text message, e.g., email, is transmitted during a data communication mode, text data of the text message is input via the operation panel **12540** and is transmitted to the central controller **12710** via the operation input controller **12640**. By the control of the central controller **12710**, the text data is transformed into a transmission signal via the modulation/demodulation unit **12660** and the communication circuit **12610** and is transmitted to the wireless base station **12000** via the antenna **12510**.

In order to transmit image data during the data communication mode, image data captured by the camera **12310** is provided to the image encoder **12720** via the camera interface **12630**. The image data captured by the camera **12310** may be directly displayed on the display screen **12420** via the camera interface **12630** and the LCD controller **12620**.

A structure of the image encoder **12720** may correspond to that of the video encoding apparatus **100** according to an embodiment. The image encoder **12720** may transform the image data received from the camera **12310** into compressed and encoded image data according to the aforementioned video encoding method, and then output the encoded image data to the multiplexer/demultiplexer **12680**. During a recording operation of the camera **12530**, a sound signal obtained by the microphone **12550** of the mobile phone **12500** may be transformed into digital sound data via the sound processor **12650**, and the digital sound data may be transmitted to the multiplexer/demultiplexer **12680**.

The multiplexer/demultiplexer **12680** multiplexes the encoded image data received from the image encoder **12720**, together with the sound data received from the sound processor **12650**. A result of multiplexing the data may be transformed into a transmission signal via the modulation/demodulation unit **12660** and the communication circuit **12610**, and may then be transmitted via the antenna **12510**.

While the mobile phone **12500** receives communication data from the outside, frequency recovery and analog-to-digital conversion (ADC) are performed on a signal received via the antenna **12510** so as to convert the received signal into a digital signal. The modulation/demodulation unit **12660** modulates a frequency band of the digital signal. The frequency-band modulated digital signal is transmitted to the image decoder **12690**, the sound processor **12650**, or the LCD controller **12620**, according to the type of the digital signal.

During the conversation mode, the mobile phone **12500** amplifies a signal received via the antenna **12510**, and obtains a digital sound signal by performing frequency conversion and ADC on the amplified signal. A received digital sound signal is transformed into an analog sound signal via the modulation/demodulation unit **12660** and the sound processor **12650**, and the analog sound signal is output via the speaker **12580** by the control of the central controller **12710**.

When in the data communication mode, data of a video file accessed at an Internet website is received, a signal received from the wireless base station **12000** via the antenna **12510** is output as multiplexed data via the modulation/demodulation unit **12660**, and the multiplexed data is transmitted to the multiplexer/demultiplexer **12680**.

In order to decode the multiplexed data received via the antenna **12510**, the multiplexer/demultiplexer **12680** demultiplexes the multiplexed data into an encoded video data stream and an encoded audio data stream. Via the synchronization bus **12730**, the encoded video data stream and the encoded audio data stream are provided to the image decoder **12690** and the sound processor **12650**, respectively.

A structure of the image decoder **12690** may correspond to that of the video decoding apparatus described above. The image decoder **12690** may decode the encoded video data to obtain reconstructed video data and provide the reconstructed video data to the display screen **12420** via the LCD controller **12620**, by using the aforementioned video decoding method.

Thus, the data of the video file accessed at the Internet website may be displayed on the display screen **12520**. At the same time, the sound processor **12650** may transform audio data into an analog sound signal, and provide the analog sound signal to the speaker **12580**. Thus, audio data contained in the video file accessed at the Internet website may also be reproduced via the speaker **12580**.

The mobile phone **12500** or another type of communication terminal may be a transceiving terminal including both a video encoding apparatus and a video decoding apparatus according to an embodiment, may be a transmitting terminal including only the video encoding apparatus according to an embodiment, or may be a receiving terminal including only the video decoding apparatus according to an embodiment.

A communication system according to an embodiment is not limited to the communication system described above with reference to FIG. **46**. For example, FIG. **47** illustrates a digital broadcasting system employing a communication system, according to various embodiments. The digital broadcasting system of FIG. **47** may receive a digital broadcast transmitted via a satellite or a terrestrial network by using the video encoding apparatus and the video decoding apparatus according to the embodiments.

In more detail, a broadcasting station **12890** transmits a video data stream to a communication satellite or a broadcasting satellite **12900** by using radio waves. The broadcasting satellite **12900** transmits a broadcast signal, and the broadcast signal is transmitted to a satellite broadcast receiver via a household antenna **12860**. In every house, an encoded video stream may be decoded and reproduced by a TV receiver **12810**, a set-top box **12870**, or another device.

When the video decoding apparatus according to an embodiment is implemented in a reproducing apparatus **12130**, the reproducing apparatus **12130** may parse and decode an encoded video stream recorded on a storage medium **12120**, such as a disc or a memory card to reconstruct digital signals. Thus, the reconstructed video signal may be reproduced, for example, on a monitor **12840**.

In the set-top box **12870** connected to the antenna **12860** for a satellite/terrestrial broadcast or a cable antenna **12850** for receiving a cable television (TV) broadcast, the video decoding apparatus according to an embodiment may be installed. Data output from the set-top box **12870** may also be reproduced on a TV monitor **12880**.

As another example, the video decoding apparatus according to an embodiment may be installed in the TV receiver **12810** instead of the set-top box **12870**.

An automobile **12920** that has an appropriate antenna **12910** may receive a signal transmitted from the satellite **12900** or the wireless base station **11700**. A decoded video may be reproduced on a display screen of an automobile navigation system **12930** installed in the automobile **12920**.

A video signal may be encoded by the video encoding apparatus according to an embodiment and may then be recorded to and stored in a storage medium. In more detail, an image signal may be stored in a DVD disc **12960** by a DVD recorder or may be stored in a hard disc by a hard disc recorder **12950**. As another example, the video signal may be stored in an SD card **12970**. If the hard disc recorder **12950** includes the video decoding apparatus according to the embodiment, a video signal recorded on the DVD disc **12960**, the SD card **12970**, or another storage medium may be reproduced on the TV monitor **12880**.

The automobile navigation system **12930** may not include the camera **12310**, the camera interface **12630**, and the image encoder **12720** of FIG. **48**. For example, the computer **12100** and the TV receiver **12810** may not include the camera **12310**, the camera interface **12630**, and the image encoder **12720** of FIG. **48**.

FIG. **48** illustrates a network structure of a cloud computing system using the video encoding apparatus and the video decoding apparatus, according to various embodiments.

The cloud computing system may include a cloud computing server **14000**, a user database (DB) **14100**, a plurality of computing resources **14200**, and a user terminal.

The cloud computing system provides an on-demand outsourcing service of the plurality of computing resources **14200** via a data communication network, e.g., the Internet, in response to a request from the user terminal. Under a cloud computing environment, a service provider provides users with desired services by combining computing resources at data centers located at physically different locations by using virtualization technology. A service user does not have to install computing resources, e.g., an application, a storage, an operating system (OS), and security software, into his/her own terminal in order to use them, but may select and use desired services from among services in a virtual space generated through the virtualization technology, at a desired point in time.

A user terminal of a specified service user is connected to the cloud computing server **14000** via a data communication network including the Internet and a mobile telecommunication network. User terminals may be provided cloud computing services, and particularly video reproduction services, from the cloud computing server **14000**. The user terminals may be various types of electronic devices capable of being connected to the Internet, e.g., a desktop PC **14300**, a smart TV **14400**, a smart phone **14500**, a notebook computer **14600**, a portable multimedia player (PMP) **14700**, a tablet PC **14800**, and the like.

The cloud computing server **14100** may combine the plurality of computing resources **14200** distributed in a cloud network and provide user terminals with a result of combining. The plurality of computing resources **14200** may include various data services, and may include data uploaded from user terminals. As described above, the cloud computing server **14100** may provide user terminals with desired services by combining video database distributed in different regions according to the virtualization technology.

User information about users who have subscribed for a cloud computing service is stored in the user DB **14100**. The user information may include logging information, addresses, names, and personal credit information of the users. The user information may further include indexes of videos. Here, the indexes may include a list of videos that have already been reproduced, a list of videos that are being reproduced, a pausing point of a video that was being reproduced, and the like.

Information about a video stored in the user DB **14100** may be shared between user devices. For example, when a video service is provided to the notebook computer **14600** in response to a request from the notebook computer **14600**, a reproduction history of the video service is stored in the user DB **14100**. When a request to reproduce the video service is received from the smart phone **14500**, the cloud computing server **14000** searches for and reproduces the video service, based on the user DB **14100**. When the smart phone **14500** receives a video data stream from the cloud computing server **14000**, a process of reproducing video by decoding the video data stream is similar to an operation of the mobile phone **12500** described above with reference to FIG. **46**.

The cloud computing server **14000** may refer to a reproduction history of a desired video service, stored in the user DB **14100**. For example, the cloud computing server **14000** receives a request to reproduce a video stored in the user DB **14100**, from a user terminal. If this video was being reproduced, then a method of streaming this video, performed by the cloud computing server **14000**, may vary according to the request from the user terminal, i.e., according to whether the video will be reproduced, starting from a start thereof or a pausing point thereof. For example, if the user terminal requests to reproduce the video, starting from the start thereof, the cloud computing server **14000** transmits streaming data of the video starting from a first frame thereof to the user terminal. If the user terminal requests to reproduce the video, starting from the pausing point thereof, the cloud computing server **14000** transmits streaming data of the video starting from a frame corresponding to the pausing point, to the user terminal.

In this regard, the user terminal may include the video decoding apparatus according to an embodiment as described above with reference to FIGS. **1** through **19**. As another example, the user terminal may include the video encoding apparatus according to an embodiment as described above with reference to FIGS. **1** through **20**. Alternatively, the user terminal may include both the video encoding apparatus and the video decoding apparatus according to an embodiment as described above with reference to FIGS. **1** through **19**.

Various applications of the image encoding method, the image decoding method, the image encoding apparatus, and the image decoding apparatus described above with reference to FIGS. **1** through **19** are described above with reference to FIGS. **42** through **48**. However, various embodiments of methods of storing the video encoding method and the video decoding method in a storage medium or various embodiments of methods of implementing the video encoding apparatus and the video decoding apparatus in a device described above with reference to FIGS. **1** through **19** are not limited to the embodiments of FIGS. **42** through **48**.

While the present disclosure has been particularly shown and described with reference to embodiments thereof, it will be understood by one of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the following claims. The embodiments should be considered in a descriptive sense only and not for purposes of limitation. Therefore, the scope of the disclosure is defined not by the detailed description of the disclosure but by the appended claims, and all differences within the scope will be construed as being included in the present disclosure.

The invention claimed is:

1. A video decoding apparatus comprising:

a splitter configured to split an image into at least one block;

a predictor configured to predict a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a first weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and

a decoder configured to decode the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

2. The video decoding apparatus of claim **1**, wherein the first weight is proportional to a difference value between the first sample adjacent to the current sample in the horizontal direction and a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction.

3. The video decoding apparatus of claim **1**, wherein the second weight is proportional to a difference value between the second sample adjacent to the current sample in the vertical direction and a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction.

4. The video decoding apparatus of claim **1**, wherein the first weight and the second weight are equal to each other.

5. The video decoding apparatus of claim **1**, wherein the first sample is located at a boundary of the current sample,

the first sample is predicted by using at least one of a value obtained by applying a fourth weight to a first reference sample outside the current block and adjacent to the first sample in the horizontal direction and a value obtained by applying a fifth weight to a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction,

the fourth weight is proportional to a difference value between the first reference sample and a second reference sample outside the current block and adjacent to the first sample in a diagonal direction, and

the fifth weight is proportional to a difference value between the third sample and the second reference sample.

6. The video decoding apparatus of claim **1**, wherein the second sample is located at a boundary of the current sample,

the second sample is predicted by using at least one of a value obtained by applying a fourth weight to a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction and a value obtained by applying a fifth weight to a first reference sample outside the current block and adjacent to the second sample in a vertical direction,

the fourth weight is proportional to a difference value between the third sample and a second reference sample outside the current block and adjacent to the second sample in a diagonal direction, and

the fifth weight is proportional to a difference value between the first reference sample and the second reference sample.

7. The video decoding apparatus of claim **1**, wherein a third sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a diagonal direction is located at a boundary of the current block,

the third sample is obtained by using at least one of a value obtained by applying a fourth weight to a first reference sample outside the current block and adjacent to the third sample in a horizontal direction and a value obtained by applying a fifth weight to a second reference sample outside the current block and adjacent to the third sample in a vertical direction,

the fourth weight is proportional to a difference value between the first reference sample and a third reference sample adjacent to the third sample in a diagonal direction, and

the fifth weight is proportional to a difference value between the second reference sample and the third reference sample.

8. A video decoding method comprising:

splitting an image into at least one block;

predicting a current sample by using at least one of a value obtained by applying a first weight to a first sample predicted earlier than the current sample in a current block and being adjacent to the current sample in a horizontal direction and a value obtained by applying a second weight to a second sample predicted earlier than the current sample in the current block and being adjacent to the current sample in a vertical direction; and

decoding the image by using a residual value of the current sample obtained from a bitstream and a prediction value of the current sample.

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